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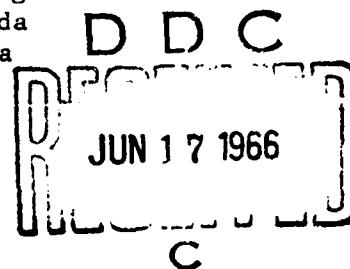
Technical Report Prepared for  
The Protective Structures Development Center  
Joint Civil Defense Support Group  
Ft. Belvoir, Virginia  
Office of the Chief of Engineers/Bureau of Yards and Docks

Contract No. DA-18-020-ENG-3580  
Subtask 1217A

Prepared by:

ENGINEERING AND INDUSTRIAL EXPERIMENT STATION  
College of Engineering  
University of Florida  
Gainesville, Florida

July 15, 1965



PROTECTIVE STRUCTURES DEVELOPMENT CENTER

FORT BELVOIR, VIRGINIA

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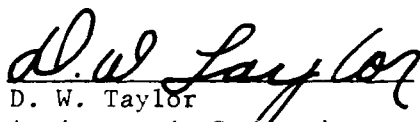
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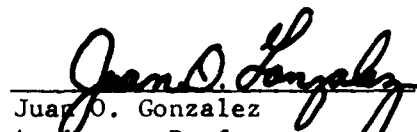
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ENGINEERING AND INDUSTRIAL EXPERIMENT STATION  
College of Engineering  
University of Florida  
Gainesville, Florida

July 15, 1965

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ABSTRACT

Ventilation studies to determine the suitability of a Package Ventilation Kit (PVK) to adequately ventilate an adiabatic, compartmented, simulated protective shelter were conducted during the period April 21 - June 26, 1965 at Protective Structures Development Center, Fort Belvoir, Virginia. The structure tested was designed to represent a typical "designated area" in the core of a multi-story building, and was erected in the basement of the 1000 Person Shelter, Building 2591, Fort Belvoir, Virginia.

A total of 1000 individual simulated occupants were installed and by adjustment of their operating voltage made to simulate 112 persons for a shelter loading rate of 1 occupant per ten square feet of floor area.

Ventilation rates of from 8 to 25 cubic feet per minute per occupant were employed; the ventilation air was conditioned in accordance with the "1% High Design Day" for the Washington (Springfield, Virginia) area. Thermal responses of the shelter as a whole and of the individual rooms were determined for both diurnal and steady-state tests.

The average thermal response of the shelter as a whole followed closely that predicted, based on an assumption of adiabatic operation, i.e., no heat transfer through the shelter boundary surfaces. Thermal responses of the individual rooms, however, departed from those predicted on an assumption that each room received a quantity of ventilation air commensurate with its occupant loading. It was apparent that rooms not in the direct flow path of the ventilation air did not receive their pro-rata share.

At no ventilation rate tested utilizing the PVK could a habitable thermal environment be maintained in all of the shelter rooms, throughout a complete diurnal cycle, as measured by a criterion of 85 F maximum effective temperature. The side rooms exhibited effective temperatures above 85 F at some time during a diurnal cycle for all air flow rates in both supply and exhaust configurations, except when these rooms were in the direct flow path of the ventilation air (Series flow) or when auxiliary air moving devices, (Punkah Pumps), were deployed. For a criterion of 85 F average effective temperature the entire shelter could be adequately ventilated by a PVK in an exhaust configuration supply 14 cfm of air per occupant when Punkah Pumps were employed and the air was conditioned to follow the diurnal cycle. For these same conditions of supply air, but with the PVK in a supply configuration, 16 cfm were required to render all rooms habitable. When Punkah Pumps were not employed, the side rooms exceeded an average effective temperature of 85 F at some time for all ventilation rates employing a complete diurnal cycle. A ventilation arrangement in which each room received in series, all of the ventilation air, produced the lowest average shelter effective temperatures.

A baffle which caused fresh ventilation air to impinge on the doorways to the "side" rooms blocked the normal egress of thermal currents and resulted in less favorable environmental conditions than when no baffle was employed.

Difficulty was experienced in the utilization of polyethylene film flexible ductwork in that flow patterns were unstable and the duct exhibited a tendency to collapse when bent to pass around obstructions. Flow through the duct could be stabilized by restraining its free end and by obstructing about one-third of the exhaust area.

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## ACKNOWLEDGEMENTS

The University of Florida wishes to express its appreciation to the staff of the Protective Structures Development Center, Fort Belvoir, Virginia for their efforts in making the test a successful operation.

In particular, we would like to thank Mr. M. M. Dembo for his helpful advice and guidance and Mr. O. W. Svaeri and Mr. N. I. Stein for their many hours of diligent assistance.

## I. FOREWORD

An investigation of the thermal response of specialized protective structures, or of areas within conventional buildings designated as shelters, is a useful preliminary to planning the ventilation equipment which must be built into or provided as part of the shelter supply and equipment package. The ventilating or cooling capacity to be provided depends on the anticipated tolerance of the shelter occupants to adverse thermal environments, on the severity of the ambient weather to be expected at the shelter location, and on the ability of the shelter structure to transfer out part of the heat released therein, rather than depending for its removal, entirely on the thermal capacity of the ventilation air.

The thermal response of a structure or area may be determined by computations using a mathematical model, by conducting a simulated occupancy test, or by actual occupancy. The first method is the most economical of time and money, but involves assumptions as to shelter geometry, thermal properties of the surroundings, and mechanisms of heat transfer which may be difficult to make or justify. The latter method, the actual "live" occupancy test, is most expensive to conduct, and if pushed to extremes, may involve danger to health. However, it is capable of answering psychological as well as physiological questions not considered in the mathematical or thermal simulation. Occupancy tests in which the actual shelter is employed, and in which the release of metabolic heat and moisture is simulated by devices, while the shelter is provided with a ventilation supply programmed to duplicate selected ambient conditions, may be expected to provide results of perhaps greater validity than the first method for less effort and danger than the latter.

The Engineering and Industrial Experiment Station of the University of Florida, Gainesville, Florida, has made a series of simulated occupancy tests at various locations throughout the United States. These tests, conducted under Contracts OCD-OS-62-116 and B-64225-(4949A-17) US, for the Office of Civil Defense, Department of Defense, have been largely concerned with shelters of simple geometry, located underground, in environments that permitted some heat loss by transfer to the surroundings. In contrast, the simulated shelter to be tested in the present investigation is of compartmented geometry, has been insulated to prevent heat transfer, and is considered to represent a typical "designated" shelter area in a multi-story building. In addition, the efficacy of air deflecting and air fanning devices is to be considered as they effect a more even distribution of environmental conditions throughout the "rooms" of the shelter.

A criterion frequently selected for evaluation of shelter environments is "effective" temperature. The "effective" temperature represents a combination of the contributions of air temperature, humidity, and motion as they affect a person's subjective evaluation of whether one environment is "better" or "worse" than another. By virtue of a multiplicity of tests, it has been possible to assign numerical values to "effective" temperatures for the environments normally encountered. In the heat stress region above 80 F "effective" temperature, there have been relatively few subjective experiments performed. There is as yet no general agreement as to the level of "effective" temperature which may be successfully tolerated for extended periods by an "average" population. The tolerance level for the

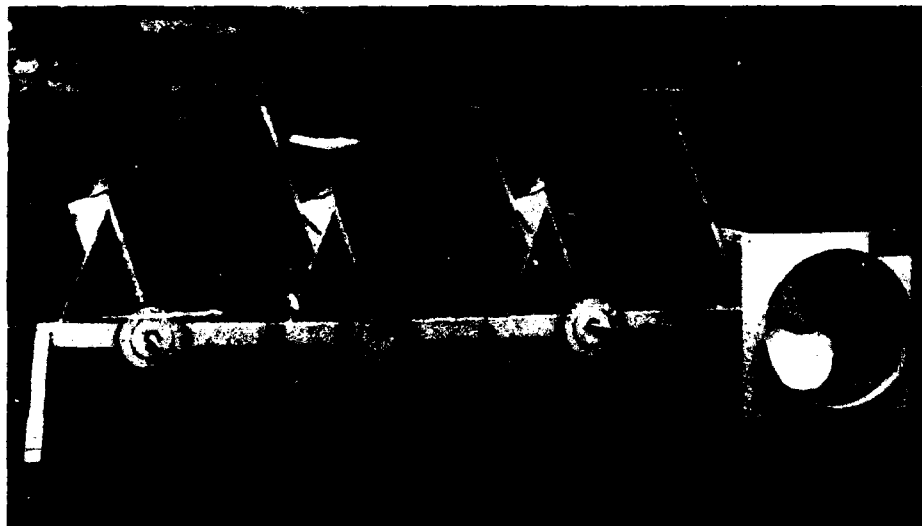
aged and infirm has also not been established. There is a question as to whether the body is irreversibly damaged by high effective temperature transients, or can tolerate these if the average "effective" temperature does not exceed some selected value. Experimental studies are being made of these problems and it is anticipated that conclusions based upon criteria of 85 degree maximum or 85 degree average effective temperature may have to be later modified. Both criteria have been considered in this investigation.

In order to supplement the natural ventilation capabilities of "designated area" shelters, air moving devices capable of being driven by muscular exertion have been developed. One such device, a Package Ventilation Kit shown in the accompanying photograph, may be driven by one to three operators. The fan capacities for various combinations of speed and duct length are indicated in the table. Not shown in the photograph, but provided as a component of the Package Ventilation Kit, is a length of polyethylene duct. By connecting this to the exhaust face of the fan assembly, the PVK can be placed deep within a shelter area and serve in an "exhaust" configuration. It may also be used in a "supply" configuration by placing it in a doorway and forcing ventilation air into a shelter.

The fan portion of a PVK was to be used to supply the ventilation air for the shelter. The scope of the present studies was to investigate its capability to ventilate the shelter, but was not to include evaluation of the fan characteristics such as power consumption, capacity, etc.

Equivalent Length of 20" Diam. Sheet Metal Duct, Ft.	E-2024-6 MODULAR DESIGN								
	1 Man Pedal Fan 41 rpm			2 Man 52 rpm			3 Man 59 rpm		
	CFM	FAN HP	P <sub>s</sub> in. Water	CFM	FAN HP	P <sub>s</sub> in. Water	CFM	FAN HP	P <sub>s</sub> in. Water
200	2000	0.09	0.12	2500	0.17	0.18	2850	0.25	0.24
300	1750	0.09	0.14	2250	0.18	0.22	2650	0.28	0.31
400	1600	0.09	0.16	2000	0.17	0.24	2450	0.27	0.34
500	1500	0.09	0.17	1900	0.18	0.26	2250	0.26	0.36
600	1450	0.10	0.19	1800	0.19	0.29	2100	0.27	0.38
800	1350	0.10	0.22	1700	0.20	0.35	1950	0.29	0.44
1000	1300	0.11	0.25	1650	0.21	0.39	1850	0.32	0.49
1370	1200	0.13	0.30						
2660	960	0.16	0.40						

**FAN AND SYSTEM CHARACTERISTICS**  
(Interim Prototype Design Ratings)



Photograph No. 1. Bicycle Fan of Package Ventilation Kit

II. OBJECT

The object of the investigation, as defined in the Contract was to make an empirical determination of the capabilities and effectiveness of selected developmental air moving devices to ventilate a compartmentalized above-ground shelter space, by measuring the distribution of ventilation air, air changes, and the thermal environment within the shelter rooms.

### III. EXPERIMENTAL DESIGN

The thermal response of a simulated protective shelter will be affected by the volume, condition, and method of distribution of the ventilation air, as well as by the conditions of loading and the thermal environment in which the shelter is located. In the case of the present study, the shelter loading was fixed at 1 occupant per ten square feet of shelter floor area, and the shelter made to approach the adiabatic mode of operation by insulation of its walls, floor, and ceiling, and by control of the temperature of the surrounding space. The remaining variables could be varied independently within limits imposed by the judgement and ingenuity of those conducting the test or by the capabilities of the ventilation equipment to be used. Criteria considered in designing the experiment are discussed below.

Effective Temperature is an index of the body's response to its thermal environment. The body must dispose of the heat which results from metabolic processes, the amount of heat so lost depending on the level of activity. For the restricted activity expected during shelter occupancy, a heat dissipation rate of 400 Btu per hour is usually assumed.<sup>1</sup> The manner and ease with which this quantity of heat is disposed of depends on the surroundings; as the temperature rises, more and more heat is lost by evaporation of moisture from the skin and lungs, as indicated in Table 1.

Table I

Observed Metabolic Heat Losses for Sedentary Adults\*

Dry-Bulb Temperature F	Sensible Heat Loss, Btu/hr	Latent Heat Loss	
		Btu/hr	Lb. water/hr
50	335	65	0.062
60	330	70	0.067
70	300	100	0.096
80	220	180	0.173
90	115	285	0.274
100	0	400**	0.384
110	-120	520	0.499

\* Values taken from 1964 ASHRAE Guide and Data Book, Chapter 30, Page 338, Table 3.

\*\* 400 Btu/Hr is equivalent to 117 Watts.

<sup>1</sup> Superscript numerals in body of report refer to Bibliography.

If the surroundings are hot, but at a low relative humidity, the body may not suffer undue discomfort and the same might be true of a cool but humid environment in which a larger proportion of metabolic heat would be lost by conduction or radiation. Various combinations of temperature and humidity might be expected to produce similar sensations or physiological responses within the body. The effective temperature index is a method of estimating the body's response to such varying conditions. Some effective temperatures are given in Table II; these values derived from a more complete presentation found in the literature.<sup>2</sup>

The ability of human beings to tolerate adverse environmental conditions has not been established and doubtless varies from individual to individual. Pending establishment of statistical norms to be used in evaluating shelter environments, three differing guide lines or criteria have been selected. One, it is assumed that an effective temperature of 85.0 F may be the upper limit of tolerance and that irreversible body damage may occur if this temperature is exceeded for even short periods. Two, it is considered that the human body may have enough overload capacity so that it can tolerate an average effective temperature of 85.0 F provided that the periods above this value do not exceed 90 F. Finally, from the standpoint of economy of ventilating power, it is felt that effective temperatures below 80 F would probably result in a shelter managerial decision to reduce fan speed consistent with the requirement of some minimum ventilation rate to prevent build up of carbon dioxide within the shelter. From these criteria, the decision was made to consider ventilation air flows which produced maximum shelter effective temperatures of 85 F, those that produced average effective temperatures of 85 F, and not to extend the investigation beyond those conditions which produced minimum effective temperature conditions of 80 F.

TABLE II EFFECTIVE TEMPERATURES  
(Air Velocity 20 Feet/Minute)

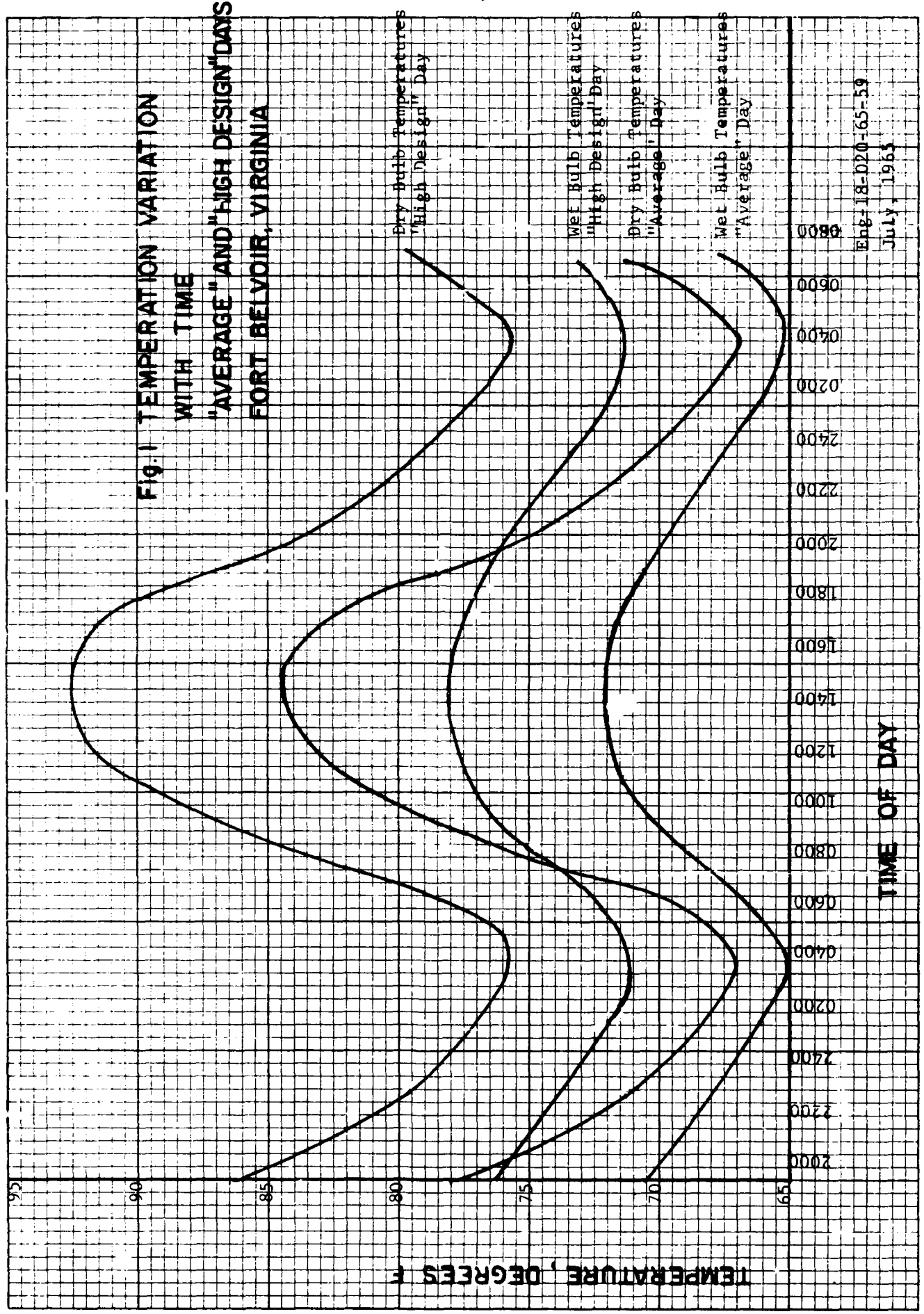
		Wet Bulb Temperature, Degrees, Fahrenheit																	
		86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
110	92.9	92.4	91.8	91.3	90.7	90.1	89.5	88.9	88.3	87.7	87.1	86.5	85.9	85.3	84.7	84.1	83.5	82.9	82.3
109	92.7	91.3	90.7	90.1	89.5	88.9	88.3	87.7	87.1	86.5	85.9	85.3	84.7	84.1	83.5	82.9	82.3	81.7	81.1
108	92.6	92.1	91.5	90.9	90.4	89.8	89.3	88.7	88.1	87.6	87.0	86.4	85.8	85.3	84.7	84.1	83.5	82.9	82.3
107	92.5	91.9	91.3	90.7	90.2	89.7	89.2	88.6	88.1	87.5	87.0	86.4	85.8	85.3	84.7	84.1	83.5	82.9	82.3
106	92.3	91.7	91.2	90.5	90.0	89.5	89.0	88.4	87.9	87.3	86.8	86.2	85.6	85.1	84.5	83.9	83.3	82.7	82.1
105	92.1	91.5	90.9	90.3	89.8	89.3	88.7	88.2	87.7	87.1	86.6	86.0	85.4	84.9	84.3	83.7	83.1	82.5	81.9
104	91.9	91.3	90.7	90.1	89.6	89.1	88.5	88.0	87.5	86.9	86.4	85.8	85.2	84.7	84.1	83.5	82.9	82.3	81.7
103	91.7	91.1	90.5	89.9	89.4	88.9	88.3	87.7	87.2	86.6	86.0	85.4	84.9	84.3	83.7	83.1	82.5	81.9	81.3
102	91.5	90.9	90.3	89.7	89.2	88.6	88.1	87.5	87.0	86.4	85.8	85.2	84.7	84.1	83.5	82.9	82.3	81.7	81.1
101	91.2	90.6	90.0	89.4	88.9	88.3	87.7	87.2	86.6	86.0	85.4	84.9	84.3	83.7	83.1	82.5	81.9	81.3	80.7
100	91.0	90.4	89.8	89.2	88.6	88.0	87.4	86.9	86.3	85.7	85.1	84.5	84.0	83.4	82.8	82.2	81.6	81.0	80.4
99	90.8	90.2	89.6	89.0	88.4	87.8	87.2	86.6	86.0	85.4	84.9	84.3	83.7	83.1	82.5	81.9	81.3	80.7	80.1
98	90.6	89.9	89.3	88.7	88.1	87.5	86.9	86.3	85.7	85.1	84.5	84.0	83.4	82.8	82.2	81.6	81.0	80.4	79.8
97	90.3	89.7	89.1	88.5	87.9	87.3	86.7	86.1	85.5	84.9	84.3	83.7	83.1	82.5	81.9	81.3	80.7	80.1	79.5
96	90.1	89.5	88.9	88.3	87.7	87.1	86.5	85.9	85.3	84.7	84.1	83.5	82.9	82.3	81.7	81.1	80.5	79.9	79.3
95	89.8	89.3	88.6	88.0	87.4	86.8	86.2	85.6	85.0	84.4	83.8	83.2	82.6	82.0	81.4	80.8	80.2	79.6	79.0
94	89.6	89.1	88.3	87.7	87.1	86.5	85.9	85.3	84.7	84.1	83.5	82.9	82.3	81.7	81.1	80.5	79.9	79.3	78.7
93	89.4	88.8	88.0	87.4	86.8	86.2	85.6	85.0	84.4	83.8	83.2	82.6	82.0	81.4	80.8	80.2	79.6	79.0	78.4
92	89.2	88.5	87.8	87.1	86.5	85.9	85.3	84.7	84.1	83.5	82.9	82.3	81.7	81.1	80.5	79.9	79.3	78.7	78.1
91	88.9	88.2	87.5	86.8	86.2	85.6	85.0	84.4	83.8	83.2	82.6	82.0	81.4	80.8	80.2	79.6	79.0	78.4	77.8
90	88.6	87.9	87.2	86.5	85.9	85.3	84.7	84.1	83.5	82.9	82.3	81.7	81.1	80.5	79.9	79.3	78.7	78.1	77.5
89	88.3	87.6	86.9	86.2	85.6	85.0	84.4	83.8	83.2	82.6	82.0	81.4	80.8	80.2	79.6	79.0	78.4	77.8	77.2
88	88.0	87.3	86.6	85.9	85.3	84.7	84.1	83.5	82.9	82.3	81.7	81.1	80.5	79.9	79.3	78.7	78.1	77.5	76.9
87	87.7	87.0	86.3	85.6	85.0	84.4	83.8	83.2	82.6	82.0	81.4	80.8	80.2	79.6	79.0	78.4	77.8	77.2	76.6
86	87.4	86.7	86.0	85.3	84.7	84.1	83.5	82.9	82.3	81.7	81.1	80.5	79.9	79.3	78.7	78.1	77.5	76.9	76.3
85	87.1	86.4	85.7	85.0	84.4	83.8	83.2	82.6	82.0	81.4	80.8	80.2	79.6	79.0	78.4	77.8	77.2	76.6	76.0
84	86.8	86.1	85.4	84.7	84.1	83.5	82.9	82.3	81.7	81.1	80.5	79.9	79.3	78.7	78.1	77.5	76.9	76.3	75.7
83	86.5	85.8	85.1	84.4	83.8	83.2	82.6	82.0	81.4	80.8	80.2	79.6	79.0	78.4	77.8	77.2	76.6	76.0	75.4
82	86.2	85.5	84.8	84.1	83.5	82.9	82.3	81.7	81.1	80.5	79.9	79.3	78.7	78.1	77.5	76.9	76.3	75.7	75.1

\* Tabular Values prepared from Effective Temperature Chart - ASHRAE Guide, 1963 - Page 111

The Condition of the Ventilation Air was determined in accordance with the adverse environmental conditions to be expected in the vicinity of Washington, D. C. (Springfield, Virginia) during a typical "hot spell" such as is occasionally experienced during the summer in this area. A five year period of data was available from the weather station at Davison Army Airfield, Fort Belvoir, Virginia. From this it was determined that the month of July was generally warmer than June or August. From the data for July, an "average" July day was determined and curves of hourly wet bulb and dry bulb temperature variation were plotted. On the same plot, the predicted wet and dry bulb temperatures for the so-called "1 percent High Design Day" were located. These values were determined from an extensive compilation of weather data for the design of cooling towers<sup>3</sup> and represent conditions whose thermal severity would normally be exceeded only one percent of the time during a typical summer. Since these were "high design" conditions they substantially exceeded the maximum values previously determined for the "average" July day. Accordingly, the entire wet and dry bulb temperature curves were shifted upward so that their maxima passed through the one percent "high design" values. The original "average day" curves, the "high design" points and the final "high design day" curves are shown on Figure 1.

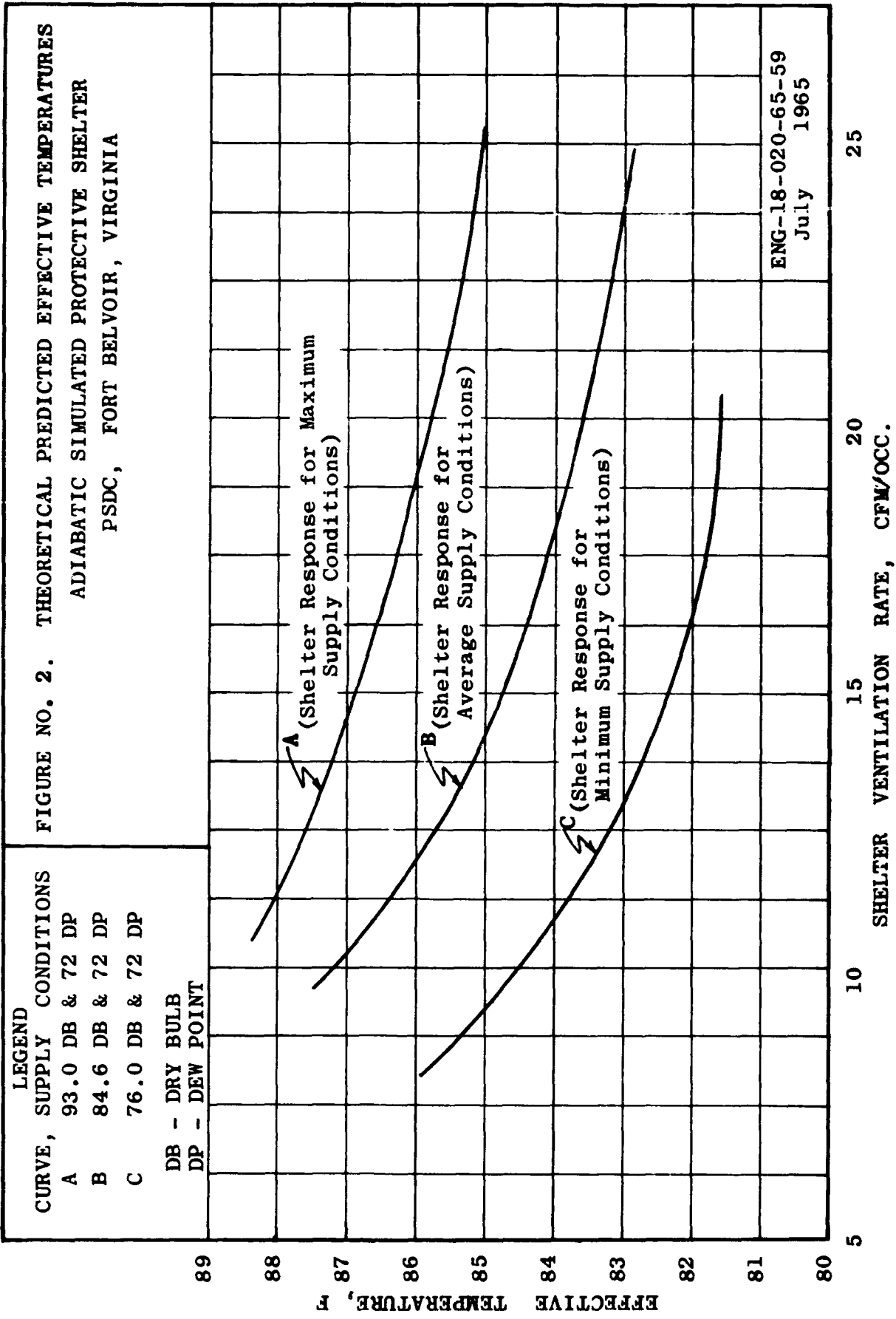
Since the Environmental Control and Instrumentation Trailer could more readily be programmed to follow a design day of constant dew point, an average dew point was determined from the "high design day" curves of Figure 1 and the equipment set to deliver air with this dew point and a variable dry bulb temperature determined in accordance with the curve for this variable.

It was contemplated that determinations of air distribution patterns and air changes would be made, and that the time involved in such procedures would be great enough that the shelter conditions might be expected to vary if the shelter was following a diurnal cycle. To obviate this difficulty, it was decided to operate the shelter at a series of selected "steady state" conditions that might be expected to occur during a diurnal cycle, yet which could be sustained long enough to permit any desired measurement to be made without change occurring in the shelter temperature. The "steady state" conditions at which it was decided to conduct tests were selected as the maximum, minimum, and average air supply enthalpies which would occur during a diurnal cycle following the "high design day". Air flows, at which these three steady-state temperatures were to be evaluated, were selected in accordance with the effective temperature limitations previously discussed and consonant with the equipment limitations considered in the section which follows.



The Volume of Ventilation Air with which it was decided to ventilate the shelter was arrived at from consideration of the properties of the ventilation air, the predicted response of an adiabatic shelter, the interim prototype design ratings of the Package Ventilation Kit fan, the capabilities of the Environmental Control and Instrumentation Trailer which was to supply the conditioned air, and the environmental tolerance limits of humans, as described in a previous section entitled "Effective Temperature". As outlined in the previous section dealing with the "Condition of the Ventilation Air", it was proposed to ventilate the shelter with air which followed a diurnal cycle of temperature and moisture variations typical of a "high design day" in the vicinity of Washington, D.C., and also to perform certain steady state tests in which constant temperature and humidity air would be supplied.

Considering the shelter to be adiabatic, it was possible to predict its overall response to supply air of known conditions. (See Appendix A). When this was done for air with the maximum, average, and minimum enthalpy values to be expected during a diurnal cycle, the curves of Figure 2 resulted. The proposed steady-state per capita ventilation rates were limited to 22.5 cfm per occupant, since this represented a total air flow near the capacity of the air handling equipment. A lower limit of 8 cfm per occupant was selected to be employed with supply air at the minimum enthalpy condition, since this extended the response curve slightly past the 85 F effective temperature point of interest. Between these limits, three other air flows were selected as indicated. The maximum steady-state air flow considered, 22.5 cfm per occupant, is at the limit of capacity of the PVK with two men operating the pedal mechanism and with 200 feet of 20 inch diameter sheet metal duct (or equivalent) attached. The maximum predicted capacity of the PVK with three operators and 200 feet of 20 inch ductwork was indicated to be 2850 cfm, which for the shelter in question would have supplied 25.4 cfm per occupant. Diurnal cycles were conducted at maximum air flow rates up to 25 cfm per occupant.



Ventilation Configurations were selected on the assumption that the shelter occupants would have available, one Package Ventilation Kit (PVK) consisting of fan, driving mechanism and 20 inch diameter plastic ducting, and that they would have some capability to close existing openings in their shelter area and open others. In addition, it was felt that they might have some ability to erect an air-directing baffle. Finally, a recent adaptation of an ancient air moving device<sup>4</sup>, the Punkah was to be employed and its effect on air distribution studied.

The three ventilation configurations and their modifications involving devices assigned to improve the ventilation of the two side rooms are shown on Figure 3. It can be seen that basically these configurations involve use of the PVK as a supply fan, as an exhaust fan in a typical compartmented area with possible "dead" areas, and as an exhaust fan in a compartmented area expediently modified structurally to eliminate spaces without forced ventilation. For Configurations 1 and 2 which involve no forced ventilation through Rooms 3 and 4, use of Punkahs and/or air directing baffles was to be considered.

Other configurations were envisioned involving the use of a baffle in a supply-fan application of the PVK and also provision of additional openings into Rooms 3 and 4, but time did not permit their investigation. For this same reason, not all the possible combinations of air temperature, air volume, and configuration could be investigated. As will appear in the section of RESULTS, some lower air flows produced intolerable environmental conditions throughout the entire shelter and after the prediction of this condition was borne out by a test, it was deemed appropriate to eliminate other tests in this area of investigation.

Of the 105 steady-state tests which the combinations of the three air temperatures, the five air flows and the seven ventilating schemes might entail, 55 were performed. The seven ventilating schemes and five air flows would involve 35 diurnal tests if all possibilities were explored; 10 were actually conducted.

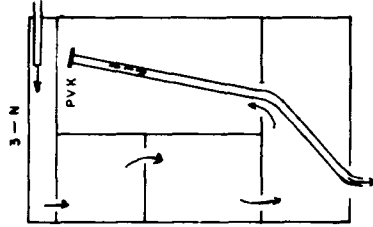
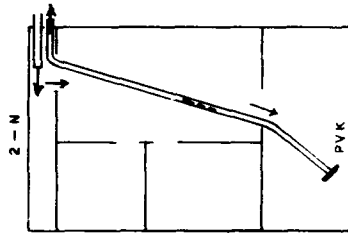
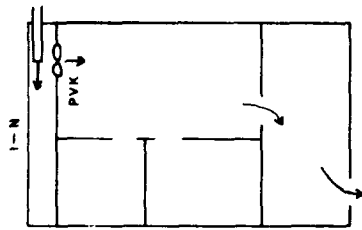
Fig. No. 3  
CONFIGURATION VARIATIONS &  
VENTILATION ADJUNCTS

ADIABATIC SIMULATED PROTECTIVE SHELTER  
PROTECTIVE STRUCTURES DEVELOPMENT CENTER  
FORT BELVOIR, VIRGINIA

CONFIGURATION LETTER LEGEND

- N — No Adjunct
- P — Pentahs in Doorway of Rooms 3B-4
- B — Baffle at Supply Location
- PB — Pentahs and Baffles Employed

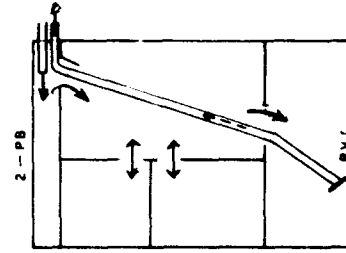
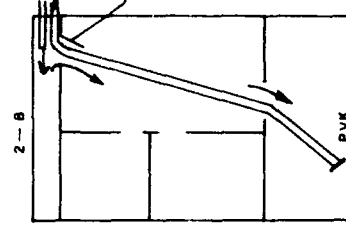
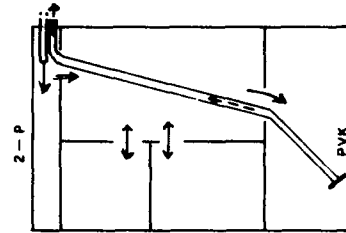
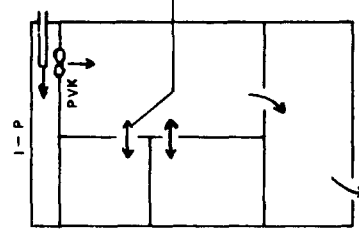
CONFIGURATION VARIATIONS (NO ADJUNCTS)



N

Note 1: Double-headed Arrows Designate Installation of Pentahs  
Note 2: 4' Wide X 7' High Baffle

CONFIGURATION VARIATIONS (WITH ADJUNCTS)



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#### IV. EQUIPMENT

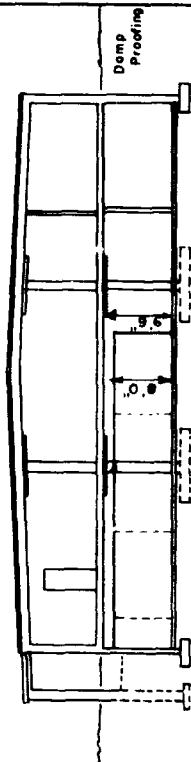
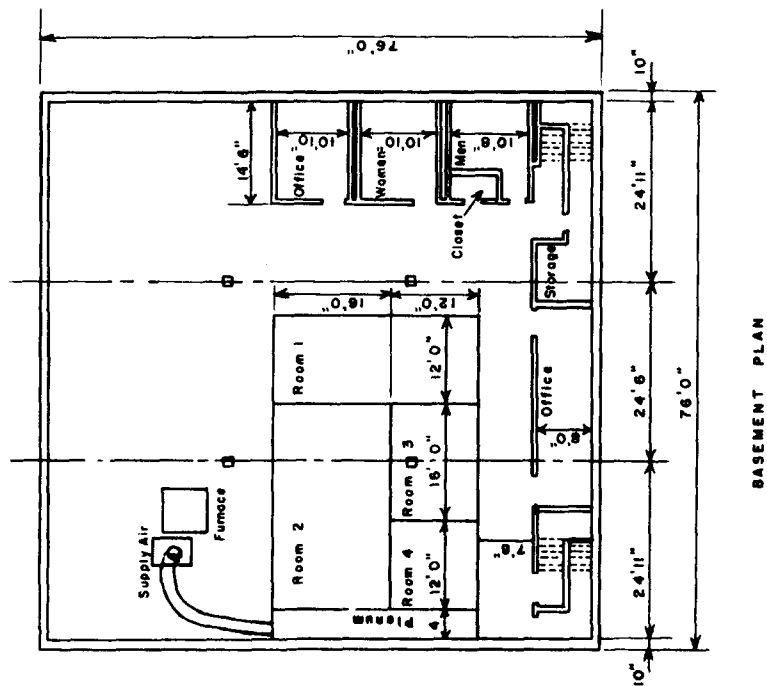
The equipment utilized in the ventilation studies herein reported, comprised a simulated protective shelter, an Environmental Control and Instrumentation Trailer designed for the conduct of controlled tests of protective structures, devices to simulate the metabolic heat and moisture releases of human beings, and miscellaneous instrumentation to measure or control the experimental variables.

The Adiabatic Shelter, which was utilized in this series of tests was designed by the Protective Structures Development Center and was constructed by Engineer troops from Fort Belvoir, Virginia. The structure simulated a "designated area" type of shelter located in the core of a multi-story building. Similar shelter areas were assumed to exist above and below the typical area under consideration. From this assumption, and the work of others<sup>5</sup> in the testing of "designated area" shelters, it was concluded that the simulated shelter should be adiabatic in operation, that is all cooling would be by ventilation air, none by heat transfer through the walls, floor or ceiling. The results of experiments conducted in such a structure would err on the side of safety, that is "real" structures of the type considered here have been found<sup>6</sup> to transfer out by conduction and radiation an amount of heat varying from zero to about 10 percent of the total released by their occupants.

To ensure a stable and controllable environment for the test structure, it was erected in the basement area of the 1000 Person Shelter, Building 2591, Fort Belvoir, Virginia. Figure 4 shows the relationship of the test shelter to Building 2591 and to the Environmental Control Unit. The original design of the structure provided for a ceiling of transparent plastic film in order to permit observation and to provide illumination. It was initially felt that thermostatic control of the temperature of the basement room would suffice to prevent heat losses from the shelter walls. A preliminary test was made of the structure as originally designed and built in order to establish the "adiabatic" quality of the test structure. Twelve pairs of thermocouples were distributed throughout the shelter in locations where temperatures on either side of the exterior walls and ceilings could be sensed. Two heat sources were placed within the shelter and adjusted to release 7.0 KW (about 50% of the total anticipated metabolic load). Temperature measurements were made until equilibrium conditions were established at an average  $\Delta T$  of 8.8 degrees. From this temperature gradient and the overall shelter boundary area (excluding the floor which was already covered with 2 inches of insulating foamed plastic), an overall heat transfer coefficient "U" value was calculated as 1.23 Btu/hr ft<sup>2</sup> deg. F.

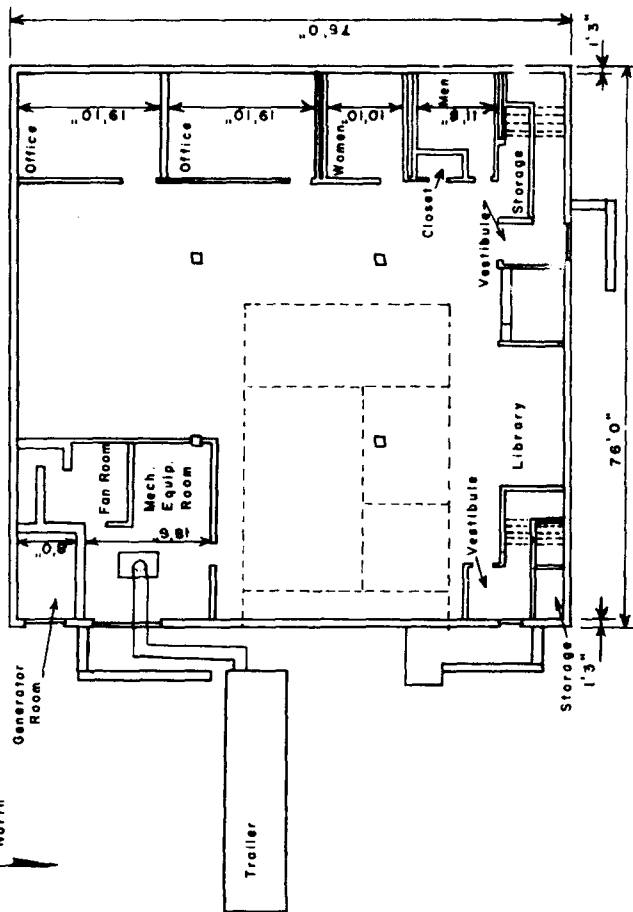
Considering the precision of other measurements to be made, it was felt that "adiabatic" operation could be assumed, if heat loss through the walls and ceiling could be kept at or below 3% of the total heat released. For the "U" value just determined, and a total heat release of 44,800 Btu/hr (112 occupants) this would imply a maximum permissible  $\Delta T$  of 0.5 degrees. This was considered to be beyond the capability of the thermostatic heat controls available.

Fig. No. 4 ADIABATIC SIMULATED PROTECTIVE SHELTER  
IN BASEMENT OF 1000-PERSON SHELTER  
FORT BELVOIR, VIRGINIA



ELEVATION

Assumed North



FIRST FLOOR PLAN

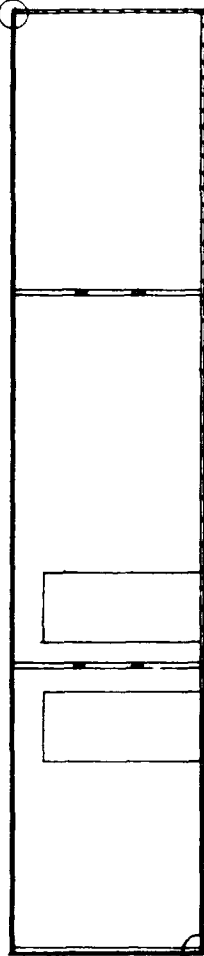
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JULY, 1965

By greatly decreasing the overall heat transfer coefficient ("U"), much higher  $\Delta T$  values could be tolerated without exceeding the 3% maximum permissible heat loss. Data from the ASHRAE "Guide"<sup>7</sup> were examined and it was determined that application of 1 inch of foamed plastic slab insulation to the exterior walls of the shelter and to the roof would reduce the "U" value to 0.171 and increase the permissible  $\Delta T$  to 3.6 degrees which was considered within the capability of the temperature control system to maintain. Calculation of the two "U" values for the shelter is outlined in Appendix A. The construction of the shelter as finally tested is shown in Figure 5. Attention is called to the fact that two types of wall construction were employed, as shown in Photograph 2, necessitating different application of insulating material and resulting in walls with differing thermal resistance. In addition, the ventilation openings shown on Figure 5 are directly applicable to Configuration 1 only and are not the same as openings provided for other Configurations (The RESULTS section for each Configuration includes a sketch of the shelter which shows the change in relative location of various ventilation openings.)

After construction, the two inch foamed plastic blocks on the floor of the shelter were covered with 6 mil plastic film which was carefully sealed to the walls. All joints in the walls were caulked and/or taped and the entire inside of the shelter was painted with a black polyester base paint to seal pores and reduce absorption of carbon dioxide during later tracer gas measurements.

The basement room, in which the simulated shelter was located, was equipped with ductwork connected to the building's heating and cooling system. During the conduct of the test, this system was split in such a way that temperature control of the basement room could be independent of that of the ground level room. In this way, the basement could be kept at or near the temperature existing within the shelter and thus the temperature drop across the shelter walls could be reduced, aiding in maintaining the "adiabatic" shelter concept. To supplement the capacity of the building's heating system, a small oil fired furnace of 150,000 Btu per hour capacity was installed in the basement, and two OCD-Mass Occupant Simulators were employed to further heat and distribute the warmed air.

See Detail II



See Detail I

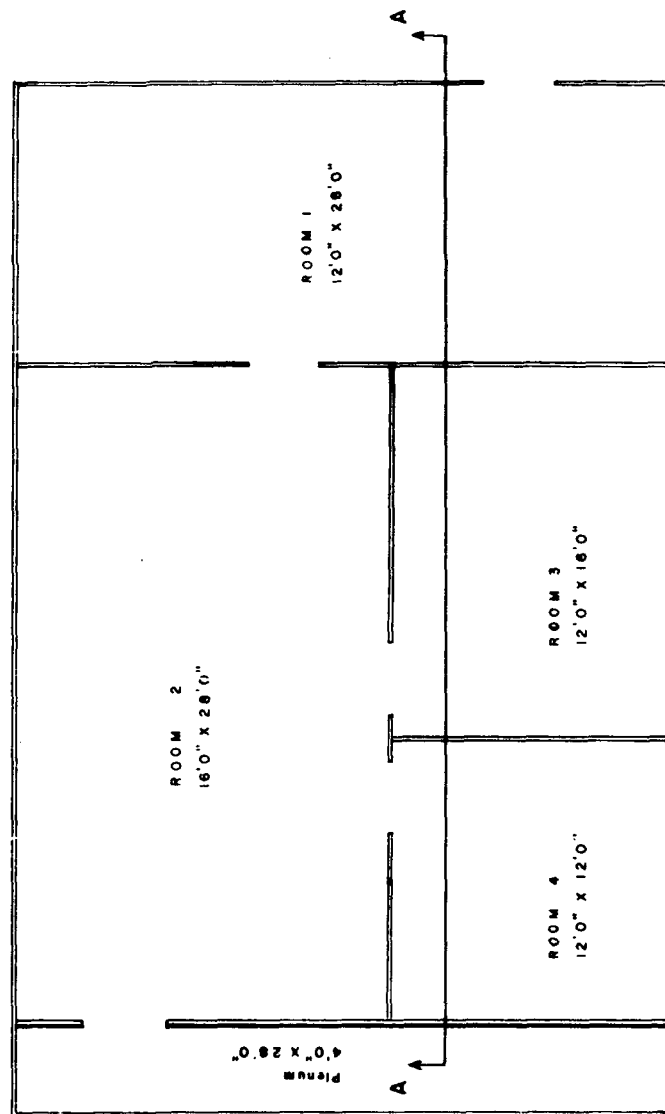


FIG. NO. 5  
FLOOR PLAN AND SECTION VIEWS  
ADIABATIC SIMULATED PROTECTIVE SHELTER  
FORT BELVOIR, VIRGINIA

1" Styrofoam

1/2" Wood Strip

Gum Base Seal

polyethylene plastic film

Rafter

1/4" Plywood

1" Styrofoam

Detail II

1/4" Plywood

Air space

Gum Base Seal

Pressure Sensitive Tape

Polyethylene plastic film

2 - 1" Styrofoam

Detail I

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JULY, 1965



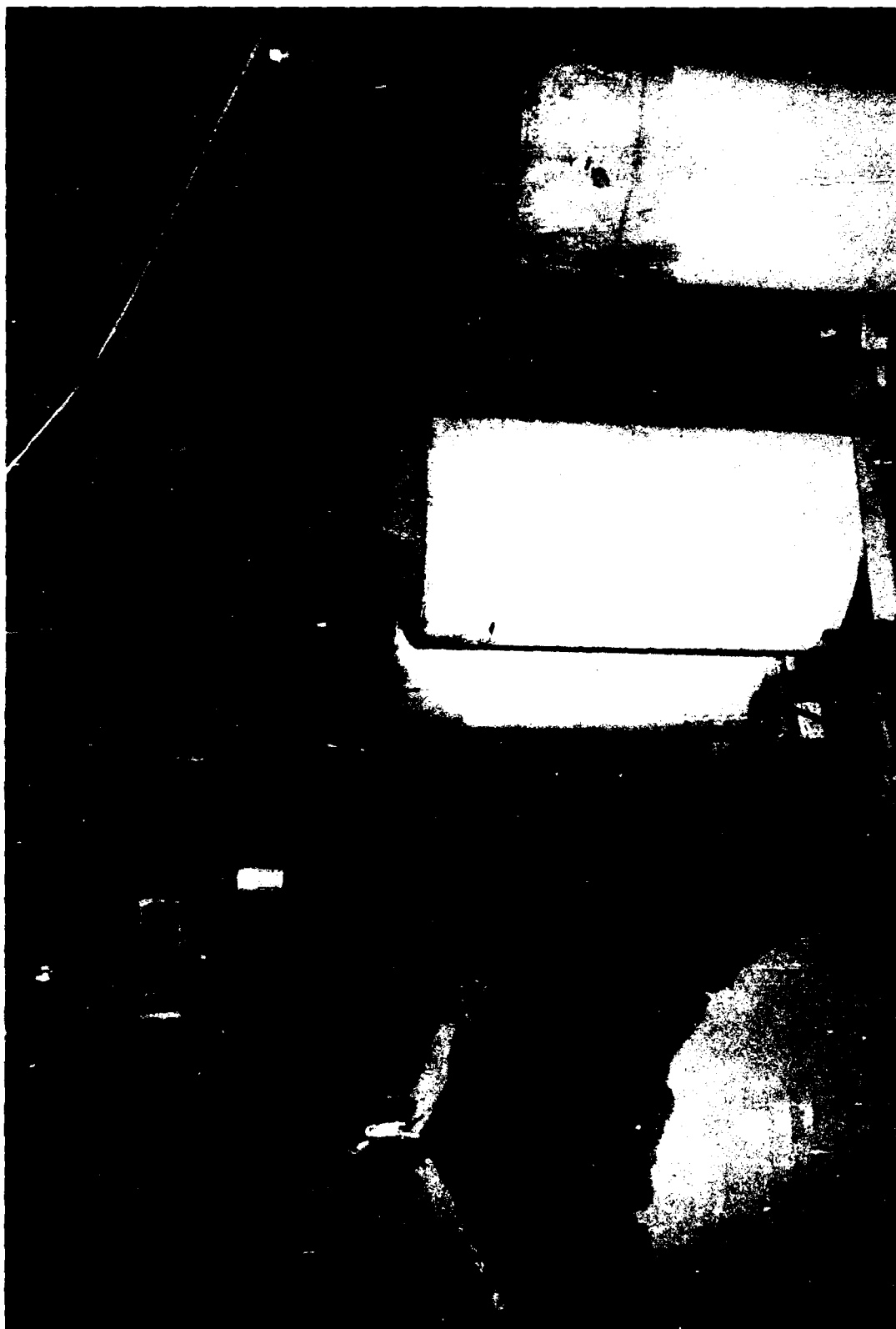
Photograph No. 2 . Exterior of "Adiabatic Shelter" (View Facing  
North East)

Simulated Occupants were used in order to "load" the shelter. These devices, familiarly labeled "Simocs", were designed to approximate the metabolic heat release of human beings. The individual type of Simoc was copied from a design originated by the United States Bureau of Standards and used by them in a pioneer test of protective shelter environment under simulated occupancy conditions. It consisted of two concentric cylinders of sheet metal, 38 inches high. The outer cylinder had a diameter of 22 inches and was closed at one end by a conical cap 5-1/2 inches high. Both the cylinder and cone were covered by a closely fitted sheath of toweling material of the type known as "huck" and commonly used for drying dishes. The inner cylinder had a diameter of 15 inches. This inner cylinder was insulated with 1/2 inch of glass fiber on its exterior surface and was open at top and bottom. The entire device rested on a two foot square sheet metal base with a retaining rim of 2 inches on all sides. At the center of this base, an electric socket was mounted and fitted with a 660-watt cone-type electric heating element. The exterior appearance and typical arrangement of the Simocs may be seen in Photograph 3.

Variable voltage transformers were employed to control the voltage impressed on the heater element of the Simoc. It might be here mentioned that transformer losses, appreciable for this type installation, were included in the heat released within the shelter and were charged to the shelter heat supply, since all power entering the shelter was metered at the shelter entrance, and the transformers were located within the shelter area.

Availability of "Simocs" limited the number which could be placed in the shelter to 100, instead of the 112 which the shelter floor area would require for the recommended loading rate of 1 occupant per 10 square feet of floor area. However by operating the cone heaters at a slightly higher voltage than normally necessary to simulate the heat generated by one individual, the output of each "Simoc" was increased approximately 12 percent so that the 100 actual Simoc units simulated 112 occupants. The cone heaters, whose rated output is 660 watts were not visibly glowing when operated at the 131 watts necessary to simulate 1-1/8 occupants each. This, coupled with the insulated inner liner of the "Simoc" reduced radiative heat transfer.

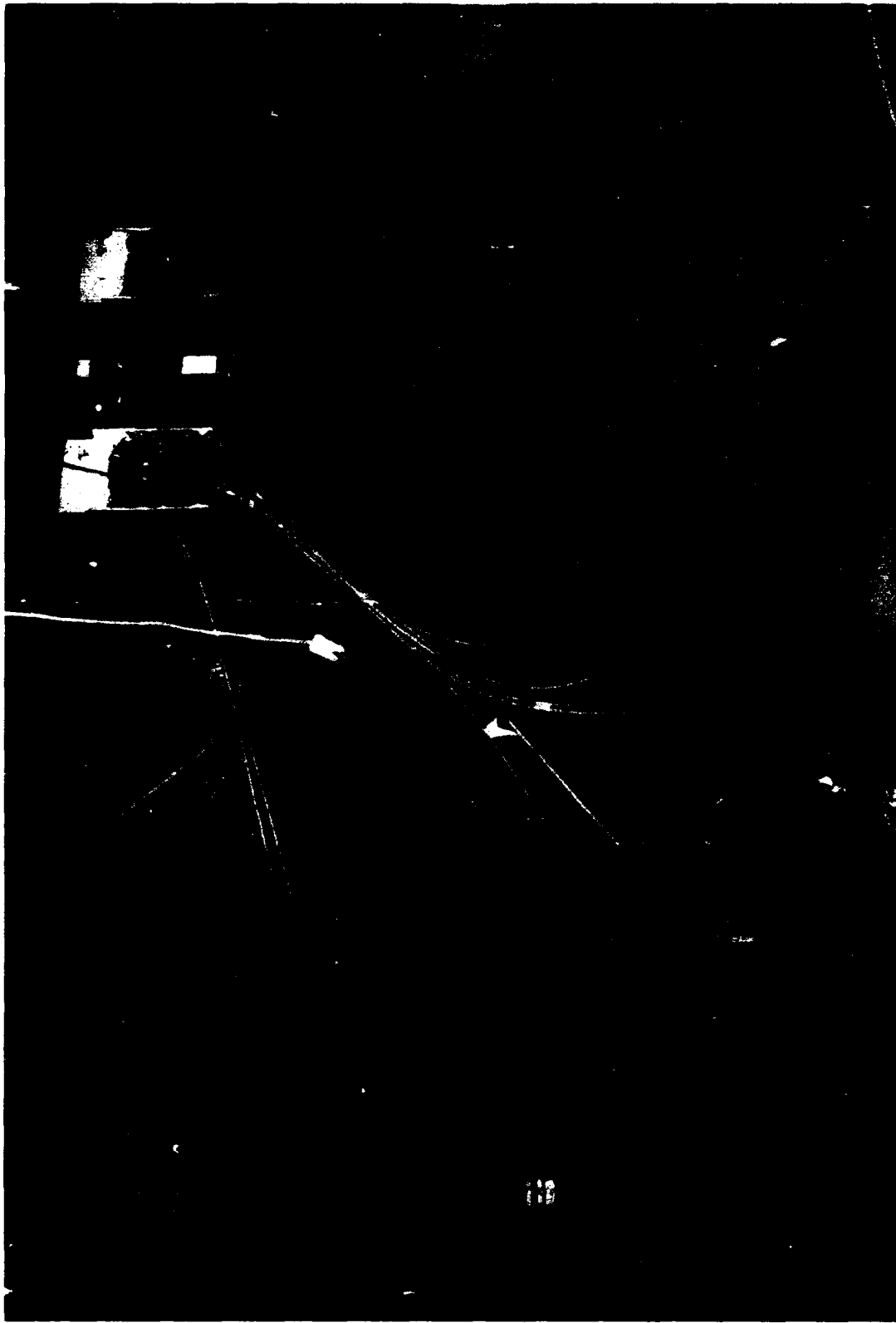
By supplying water to the apex of the cone which made up the "head" of the Simoc, the entire top and a circumferential band of cloth could be wetted. The heat from the device caused the water to evaporate, thus simulating the latent heat release from the skin and lungs of a human occupant. Since the total heat output of the electric resistance element was kept constant, the latent heat fraction could be varied as more or less water was supplied.



Photograph No. 3 . Typical Installation of Simocs in Room 4  
(View Facing North)

Water was supplied to the Simocs via individual supply lines from a rotary metering device (one such device is shown in Photograph No. 4). The metering device was driven by a 3 rpm clock drive motor connected in series with a rotating cam switch whose relative periods of "on" and "off" operation could be manually adjusted. In this fashion, the amount of water supplied the Simocs, and hence the latent heat fraction of the total heat released, could be varied in accordance with the values shown in Table I. Here it may be seen that the latent heat fraction of the total load varies directly with the dry bulb temperature. At and above 100 F, all heat lost by the body is by evaporation of moisture. Six metering devices or units were in service during the test program (two units were employed in Room 1, two in Room 2, and one each in Rooms 3 and 4).

At the beginning of the test, all of the metering devices were programmed by a single rotating cam and therefore, all units delivered water at the same rate. It early became apparent however, that dry bulb temperatures in the various rooms would differ significantly and that different water rates would therefore be required. Test 1 of the complete testing program was conducted under these conditions, after which additional metering tanks and timers were installed and the water supply to the rooms controlled separately in accordance with the temperature in that room.



Photograph No. 4 . Simoc Water Distribution Unit and Delivery  
Tubes (South East Corner of Room 1)

### Shelter Air Supply

As mentioned in the section entitled "The Adiabatic Shelter", the structure to be tested was designed to simulate a "designated area" shelter space in the core of a multi-story building. Ventilation of such spaces may be assumed to be by outside air at essentially ambient conditions. This air might be forced through the shelter by the pressure of wind, by thermal "stack effects", or, as in the configurations tested in this series of experiments, by a Package Ventilation Kit. In any case, a realistic simulated occupancy test must include furnishing the ventilation air at conditions appropriate for the period being simulated. For the series of tests under discussion, this period was to be a typical "hot spell" occurring during summer months in the vicinity of Washington, D.C. As explained in the section entitled "Experimental Design", this involved certain steady state air conditions as well as complete diurnal cycles in which air conditions changed hourly.

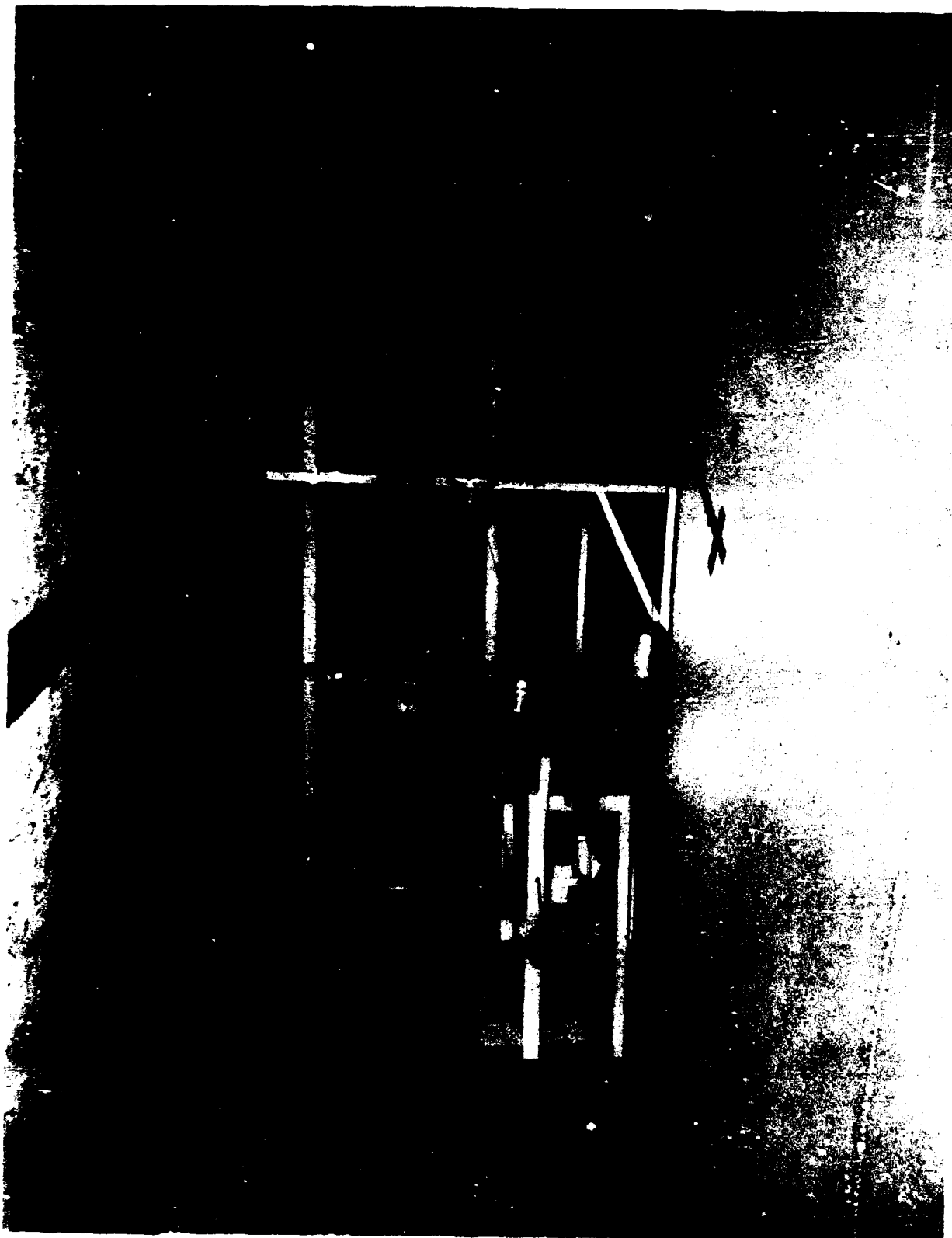
In order to provide the desired control of the shelter ventilation air supply conditions, use was made of an Environmental Control and Instrumentation Trailer built for the Office of Civil Defense for tests similar to those to be conducted. Essentially, this comprised an adjustable volume air handling unit supplying a combination air washer and reheat section. The air washer could be supplied with either heated or refrigerated spray water and hence could deliver air at a selected constant dew point to the reheat section. The reheat coils were supplied with thermostatically controlled hot water and could thus deliver the air at a selected dry bulb temperature. The dew point of the conditioned air was manually adjusted, while the dry bulb temperature was controlled by a rotating plastic cam whose profile was cut to represent the variations in dry bulb temperature occurring during the type day selected for simulation. The orientation of the Environmental Control Unit with respect to Building 2591 may be seen in Photograph 5.

The air was delivered to a plenum at the east end of the shelter via a combination of rigid and flexible ductwork. As shown on Figure 4, this duct entered an exhaust opening in the equipment room of the upper floor of Building 2591 and thus reached the lower floor.

During the operation of the test, the air supply to the shelter was adjusted as follows. The desired steady-state or diurnal conditions of temperature and dew point were selected (see section, "Design of Experiment"), as was the air flow rate. A preliminary adjustment was made in the speed or the volume controls of the main fan in the Environmental Control Trailer. The voltage control to the PVK unit's driving motor (1/4 H.P., D.C.) was adjusted until an auxiliary duct into the shelter air supply plenum indicated no flow into or out of the plenum. Under these conditions, pressure in the plenum was essentially atmospheric and it could be assumed that all the air supplied to the plenum was being utilized by the PVK and supplied to the shelter. A traverse was then made of the main supply duct at its exhaust into the plenum, and the flow rate computed. If the desired flow rate was not obtained on the first trial, the speed of the main fan was readjusted, as indicated, and the

speed of the PVK fan changed to again produce atmospheric pressure in the plenum. This process was continued until the desired air flow was being delivered to the shelter via the plenum which was being kept at atmospheric pressure by the PVK unit. A portion of the plenum is shown in Photograph 6. The main and auxiliary ducts may be seen in the background, the PVK fan in the foreground. The shelter side (or delivery side) of the fan installation is shown in Photograph 7. The shroud around the fan is readily apparent.



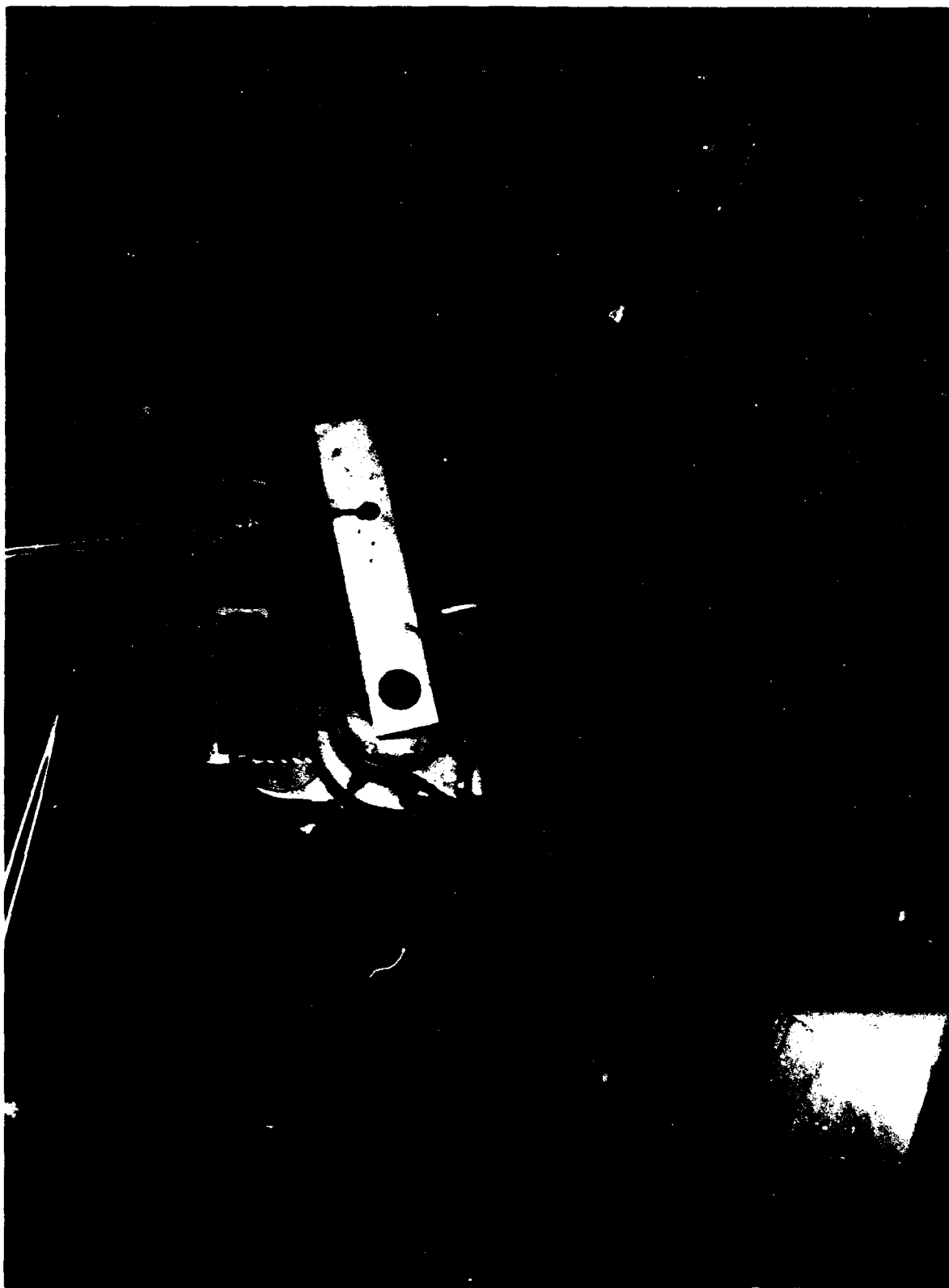




Photograph No. 7 .      Adaptation of PVK as Supply Fan -  
Configuration 1-N (View from Room 2  
facing East)

Punkah Pumps were evaluated, as devices to improve the ventilation patterns of the two side rooms, by comparing the environmental conditions which developed without the Punkahs with conditions after these devices had been in operation for several hours. The tests were made with identical shelter supply air rates and temperatures. The Punkah-pump, a recent invention based on an ancient air fanning device, consists of a pendulum-like frame covered with light vanes hinged so that when the frame swings in one direction the vanes open and offer little resistance to the air passing through the frames. During the swing in the opposite direction, or "power" stroke, the vanes swing shut, the frame now offers the resistance of an essentially solid panel to air flow, hence it moves a volume of air ahead of it, while a commensurate volume moves in behind the Punkah to prevent a vacuum from forming. Since the air in motion has inertia, the Punkah on the next "return" stroke with its vanes open, swings through the moving air without appreciably impeding its established flow. Thus uni-directional, albeit pulsing, air flow is established.

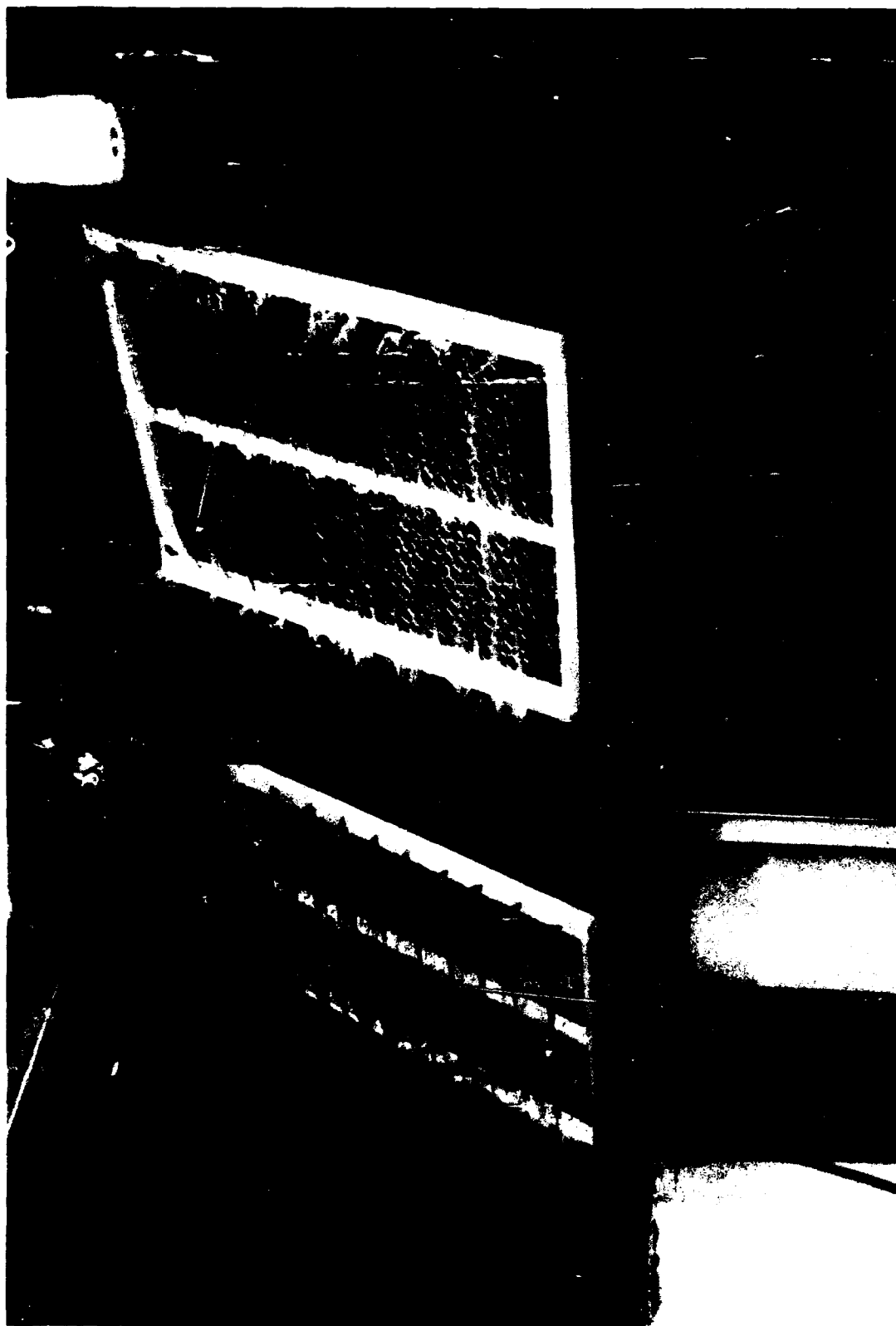
When installed in a doorway, the Punkah is capable of moving air between rooms, the effect of which may be to improve environmental conditions in a previously poorly ventilated area. Although additional improvement in ventilation patterns might have been accomplished by installing the Punkah in the bottom half of the doorways, the necessity of frequent access to the side rooms dictated its use in the upper half of the doorways of Rooms 3 and 4. Photograph 8 shows the variable-speed drive mechanism employed to drive the two Punkahs in simulation of the expected manual operation. The "power" and "return" strokes of the device may be seen in Photographs 9 and 10.



Photograph No. 8 . Variable Speed Drive Unit Used to Actuate  
Punkah Pumps



Photograph No. 9 . Operation of Punkah Pump Immediately Prior to "power" Stroke (Note: punkah flaps are about to close)



Photograph No. 10. Operation of Punkahs Pumps During "Return" Stroke (Note "Opened" Position of Punkah Flaps)

## Instrumentation

Conduct of a simulated occupancy test of a shelter area required measurement and control of the mass and energy streams to and from the shelter as well as sufficient determinations of environmental parameters to establish the thermal response of the test area.

The general instrumentation layout is shown schematically on Figure 6; functions and more exact locations of instruments are presented in Tables III and IV. A brief discussion of the variables measured and the equipment used follows.

Temperatures were generally measured with copper-constantan thermocouples, indicated and recorded on multi-point, recording potentiometers. Forty thermocouples were placed at a number of locations in contact with interior and exterior wall surfaces, to measure temperature drops across the walls for use in controlling the environment exterior to the shelter. Within the shelter proper, vertical arrays of thermocouples located as shown on Figure 6 were used to determine the degree of temperature stratification. Wet and dry bulb temperatures of the supply and exhaust air were taken with thermocouples embodied in aspirating psychrometers. Locations of these instruments varied with the ventilation configuration being studied.

Air Flow to the shelter was determined by means of a multi-point velocity traverse of the supply duct using an Alnor, direct displacement, vane-type anemometer.

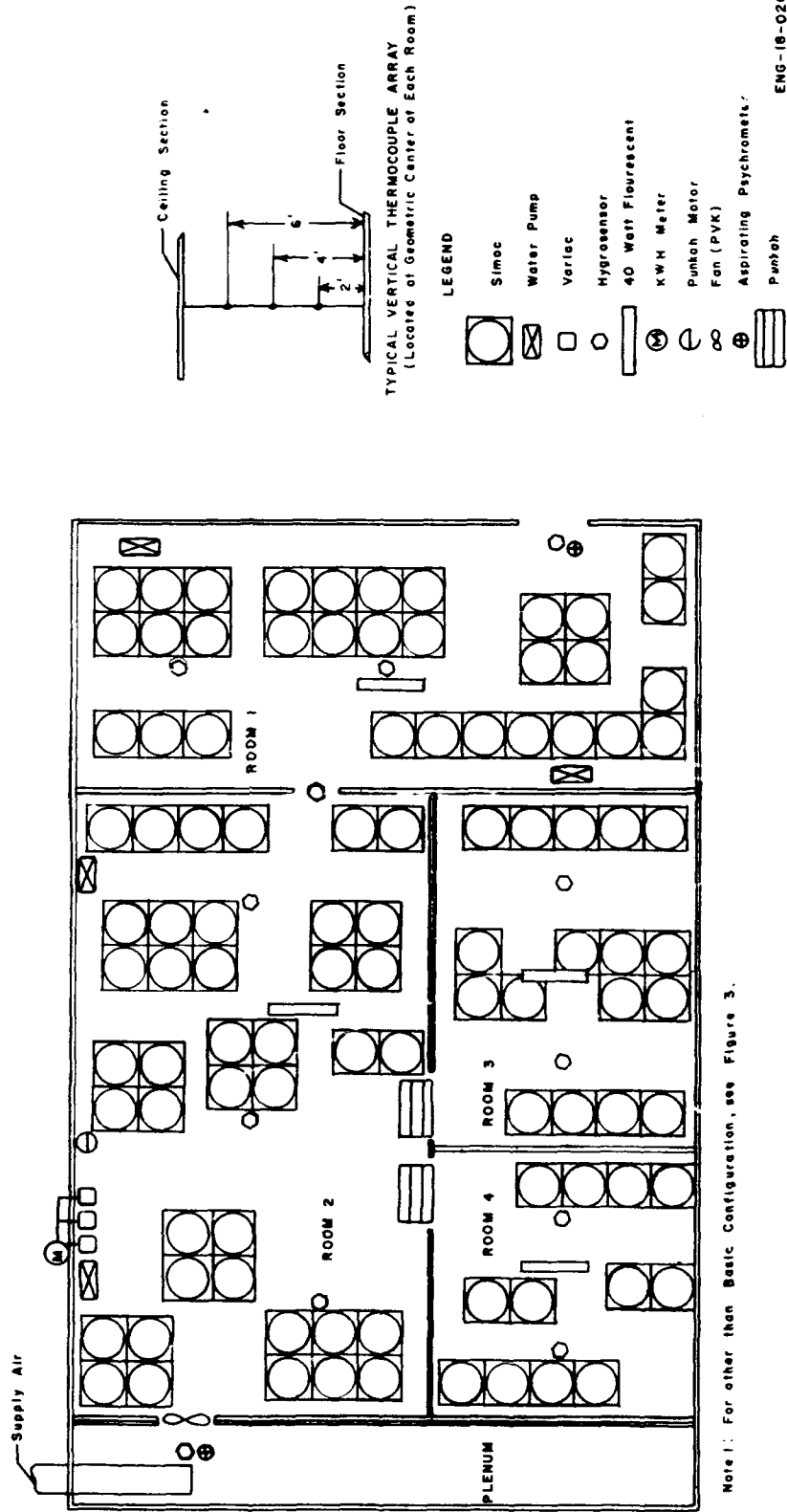
Humidity of the air at numerous locations within the shelter was measured with "Hygrosensors", humidity sensing devices manufactured by the Hygro-dynamics Corp. of Silver Spring, Maryland. These devices also incorporated a resistance thermometer, and in operation the indicated relative humidity and temperature were used as entries to psychrometric charts from which wet bulb temperature was determined. This provided data sheet entries of dry and wet bulb temperatures suitable for an established routine from which effective temperatures could be computed.

At selected times, rather extensive psychrometric "traverses" were made of the entire shelter using Bendix, electrically aspirated, mercurial thermometer, psychrometers. Two operators usually performed this task, taking readings on four foot centers throughout the shelter alternately at 5' above the floor and at 1' above the floor.

Water Flow to the "Simocs" was regulated as described in the section entitled "Simulated Occupants" and was measured by periodic readings of calibrated sight glasses on separate supply tanks for each room.

Power consumed was determined by a three phase, network type watt-hour meter which could measure both 208 volt and 120 volt demands. Except for the direct current motor driving the shelter ventilation fan, and the motor which drove the "Punkahs", when these devices were in use, all power consuming devices were supplied through the watt-hour meter.

FIG. NO. 6 EQUIPMENT DIAGRAM  
ADIABATIC SIMULATED PROTECTIVE SHELTER  
FORT BELVOIR, VIRGINIA



Note 1: For other than Basic Configuration, see Figure 3.

TABLE III  
Hygrosensor Locations  
Adiabatic Simulated Protective Shelter  
Protective Structures Development Center  
Fort Belvoir, Virginia

<u>Data Position Number*</u>	<u>Hygrosensor Head Number</u>	<u>Function**</u>	<u>Location</u>
1	1	Exhaust air, dry bulb	Depends on test configuration number***
2	1	Exhaust air, wet bulb	Depends on test configuration number***
3	2	Air temperature, dry bulb	Geometric Center, Room 1
4	2	Air temperature, wet bulb	Geometric Center, Room 1
5	3	Air temperature, dry bulb	Geometric Center of South third of Room 1
6	3	Air temperature, wet bulb	Geometric Center of South third of Room 1
7	4	Air temperature, dry bulb	Geometric Center of West third of Room 2
8	4	Air temperature, wet bulb	Geometric Center of West third of Room 2
9	5	Air temperature, dry bulb	Geometric Center, Room 2
10	5	Air temperature, wet bulb	Geometric Center, Room 2
11	6	Air temperature, dry bulb	Mid height, North section of East third of Room 2
12	6	Air temperature, wet bulb	Mid height, North section of East third of Room 2
13	7	Supply air, dry bulb	Depends on test configuration number***
14	7	Supply air, wet bulb	Depends on test configuration number***

TABLE III, CONTINUED

<u>Data Position Number*</u>	<u>Hygrosensor Head Number</u>	<u>Function**</u>	<u>Location</u>
15	8	Air temperature, dry bulb	Geometric Center of West half of Room 3
16	8	Air temperature, wet bulb	Geometric Center of West half of Room 3
17	9	Air temperature, dry bulb	Geometric Center of East half of Room 3
18	9	Air temperature, wet bulb	Geometric Center of East half of Room 3
19	10	Air temperature, dry bulb	Geometric Center of East half of Room 4
20	10	Air temperature, wet bulb	Geometric Center of East half of Room 4
21	11	Air temperature, dry bulb	Geometric Center of West half of Room 4
22	11	Air temperature, wet bulb	Geometric Center of West half of Room 4
23	12	Air temperature, dry bulb	Mid height doorway, Room 1 to Room 2
24	12	Air temperature, wet bulb	Mid height doorway, Room 1 to Room 2

\* Position number corresponds to tabulated temperature data in APPENDIX B-2

\*\* Wet bulb functions were derived from psychrometric chart using dry bulb temperature and relative humidity values obtained from each Hygrosensor head.

\*\*\* See "Results" section of each configuration for exact location of supply and exhaust.

TABLE IV  
Thermocouple Locations  
Adiabatic Simulated Protective Shelter  
Protective Structures Development Center  
Fort Belvoir, Virginia

<u>Data Position Number*</u>	<u>Function</u>	<u>Location</u>
25	Supply air, dry bulb	Depends on test configuration number**
26	Supply air, wet bulb	Depends on test configuration number**
27	Exhaust air, dry bulb	Depends on test configuration number**
28	Exhaust air, wet bulb	Depends on test configuration number**
29	Ambient air, dry bulb	Not taken
30	Ambient air, wet bulb	Not taken
31	Air temperature, Room array	Center of Room 1, 2 feet above floor
32	Air temperature, Room array	Center of Room 1, 4 feet above floor
33	Air temperature, Room array	Center of Room 1, 6 feet above floor
34	Air temperature, Room array	Center of Room 2, 2 feet above floor
35	Air temperature, Room array	Center of Room 2, 4 feet above floor
36	Air temperature, Room array	Center of Room 2, 6 feet above floor
37	Air temperature, Room array	Center of Room 3, 2 feet above floor
38	Air temperature, Room array	Center of Room 3, 4 feet above floor
39	Air temperature, Room array	Center of Room 3, 6 feet above floor
40	Air temperature, Room array	Center of Room 4, 2 feet above floor

TABLE IV, CONTINUED

<u>Data Position Number*</u>	<u>Function</u>	<u>Location</u>
41	Air temperature, Room array	Center of Room 4, 4 feet above floor
42	Air temperature, Room array	Center of Room 4, 6 feet above floor
43	Surface temperature	In contact with top surface of floor insulation, Geometric Center of Room 1
44	Below floor level temperature	In contact with bottom surface of insulation, 2 inches below floor level, Geometric Center of Room 1
45	Surface temperature	In contact with top surface of floor insulation, Geometric Center of Room 2
46	Below floor level temperature	In contact with bottom surface of insulation, 2 inches below floor level, Geometric Center of Room 2
47	Exhaust temperature, dry bulb	Center of 20 inch plastic duct prior to exit from shelter
48	Reference, water bath	Environmental Control Trailer, instrumentation cab
49	Reference, water bath***	Environmental Control Trailer, instrumentation cab

---

\* Position numbers correspond to tabulated temperature data in APPENDIX B.

\*\* See "Results" section or Figure Number 3 for exact location of supply and exhaust.

\*\*\* Temperature of water bath as indicated on mercurial thermometer. (Same location as position No. 48).

## OPERATIONAL PROCEDURES

The conduct of the air distribution studies herein reported comprised two types of shelter response tests each repeated a number of times at different selected values of some important parameter. These were the steady-state, and the diurnal cycle tests. In addition, there were a number of adjunct tests which were made with less regularity. In order that some familiarity be gained with the sequence and frequency of typical measurements, a brief outline of the major operational procedures follows.

The Diurnal Test comprised a period of from 48 to 120 hours during which the shelter was furnished with an air supply whose dry bulb temperature and dew point were varied in simulation of the ambient conditions that would be expected in the shelter vicinity during very warm summer weather. The way in which these supply air conditions were arrived at is discussed in a subsection entitled "Condition of the Ventilation Air". An air flow rate, which calculations indicated should result in an overall shelter effective temperature of either a maximum or an average of 85 F, was selected. The air flow rate was set in the supply duct to the shelter and measured by a 16 point velocity traverse using a vane-type direct displacement anemometer. The air flow was subsequently checked once during each twenty-four hour period, or oftener if there was reason to suspect that it might have been altered.

An initial setting was made of the timing devices of the water measuring and distributing mechanisms, in accordance with the values of Table I and the dry bulb temperature then existing in each room of the shelter. Subsequently, the water level was measured in the tank supplying water to each room, at two hour intervals and compared with the desired rate determined from the values of Table I in accordance with the dry bulb temperature in the space at a time halfway between tank level readings. An appropriate change was made in the timer cycle to increase or decrease the water rate to follow the cycling dry bulb temperatures in the four shelter rooms.

At two hour intervals, the shift operator would read and average a group of temperatures from forty thermocouples located in twenty pairs on inner and outer faces of the shelter structure. From these readings, he would establish an average  $\Delta T$  from the interior to the exterior of the shelter. Using the controls of the building heating system, supplemented by an auxiliary, oil fired heater in the basement, the operator would adjust the temperature of the space surrounding the shelter to reduce the temperature drop across the shelter walls to a minimum.

At hourly intervals, the operator would read the dry bulb temperature and relative humidity indicated by 11 Hygrosensors located throughout the shelter as shown on Figure 6. Using a psychrometric chart, he would read the wet bulb temperatures determined by these values of temperature and relative humidity and record this data, which is presented in Table II, Appendix B. Additional data were automatically recorded each hour for temperatures measured at the locations shown on Figure 6.

The shift operator, assisted by supervisory personnel, maintained running plots of the environmental conditions as they developed within the shelter. These plots were valuable in detecting anomalies of shelter response which were usually found to be due to errors in procedure. At the end of about thirty-six hours, it was usually possible to begin comparisons of the then existing shelter conditions with those twenty-four hours earlier. When such comparisons indicated that a twenty-four hour cycle had been duplicated, it was assumed that the shelter had attained a stable equilibrium, and the diurnal test was terminated after the shelter had reached and passed the next afternoon peak effective temperatures. In general, the overall duration of such a test depended on the previous history of the shelter, being longer when a major change in ventilation rate or configuration was made.

It was customary during the conduct of a diurnal cycle test to make two detailed traverses of the shelter and determine wet and dry bulb temperatures on four foot centers throughout the entire structure. Usually two Bendix, aspirating psychrometers were employed with two operators making readings at alternate "low" (12 inches above the floor) and "high" points (60 inches above the floor). The locations at which "low" readings could be taken were usually dictated by the placement of Simocs, ductwork, or other equipment with the "high" locations being governed by the remaining points. The traverses were customarily made at the time when the shelter was experiencing maximum effective temperatures (usually about 1400 to 1500 hours) and again during the early morning hours when minimum conditions were prevalent.

The Steady-State Tests were conducted in much the same manner as the diurnal cycle, except that as its name implies, the properties of the ventilation air were held constant until the shelter reached a stable equilibrium. This usually occurred in from eight to sixteen hours of operation.

Air Change and Air Exchange Measurements were considered of importance in evaluating the thermal response of the compartmented simulated shelter as a whole, and as individual rooms. Similarly, the air exchange across the doorways of Rooms 3 and 4, where bi-directional air flow existed, was considered of significance. For this reason, attempts were made to determine the various flows by the three independent methods; direct velocity measurement, heat balance, and tracer gas to be described. It must be emphasized at the outset, that only at the shelter air inlet and shelter exhaust could air flows be measured without ambiguity; at any interior location, determinations were complicated by streams of recirculating air whose presence could be demonstrated, but whose penetration into the particular volume under study could only be estimated. Even for the rooms where the air entered or exited, the term "air change per unit time" must be interpreted with caution. As an example, for Ventilation Configuration Number I, and for a shelter ventilation rate of 18 cfm per occupant, the air changes per hour were 33.8 for Room 2 and 45.0 for Room 1, yet for this configuration and air flow, the effective temperature in Room 1 was always higher than for Room 2, this of course because the air moved through Room 2 first in this configuration.

Direct velocity measurements were attempted in the doorways between Room 2 and Rooms 3, 4, and 1, utilizing both hot wire anemometers developed by the Flow Corporation, and a vane-type, direct displacement meter of

the Alnor, Corporation. Neither instrument was found to be entirely satisfactory in application. When used on a scale low enough to give definite indications, the random air currents were sufficient to drive meter needles off scale in both directions. Only extended periods of observation permitted the operator to mentally integrate the readings. Nevertheless, it was usually possible to establish that bi-directional flow existed in the doorways to Rooms 3 and 4, and uni-directional flow was present in the doorway between Rooms 1 and 2.

Velocity measurements were also made throughout the shelter, together with simultaneous emission of smoke puffs as shown in Photograph 11.

An attempt was made to make similar traverse of the shelter using a narrow-range humidity sensing instrument, but the response time of the instrument, when moved from a higher to a lower relative humidity region, was prohibitively long.

Heat balances were also attempted as a means of estimating the flow of air to the two interior rooms. In this method of measurement, advantage was taken of the fact that heat transmission losses from these rooms were greatly reduced by the insulation employed on the floor and ceiling, as well as on the exterior walls. A correction for the losses actually present could be made based on the known temperature drop across the room boundaries. The heat release within the room was known from watt-hour meter readings made at intervals throughout the test period. A measurement of relative humidity and temperature by a Hygrosensor (see section on Instrumentation) located near the center of the space in question permitted an estimate to be made of the enthalpy of the air within the room. Psychrometric measurements made in the doorway gave data from which the enthalpy of the entering (or leaving) air could be determined. From the known heat release and the enthalpy increase of the ventilation stream, the mass flow rate of the stream could be determined. In the determination of the "average" inlet or exhaust enthalpy, measurements indicated that properties of the air varied over the area of the doorway in much the same manner as had been found for the velocity determinations.



Photograph No. 11. The Application of "Smoke" Generation to  
Determine Air Currents

Tracer gas techniques were also employed to gain some insight as to air change phenomena. In this method of measurement, a room to be tested was first charged with CO<sub>2</sub> gas (added by means of a tube discharging in the center of the room), until a CO<sub>2</sub> analyzer indicated that a desired concentration of gas had been built up. The supply of CO<sub>2</sub> gas was shut off and continuous measurements made of the decreasing concentration of tracer gas in the test area. Assuming complete mixing of the ventilation air and that present in the room, the concentration of the tracer gas during the decay period is given by:

$$-V \frac{dC}{dt} = QC$$

Where:

C = Concentration of tracer at time t

Q = Ventilation rate to room

V = Volume of room

For initial conditions, C = C<sub>0</sub> and t = 0, the solution is:

$$C = C_0 e^{\frac{-Qt}{V}} = C_0 e^{-nt}$$

From which:

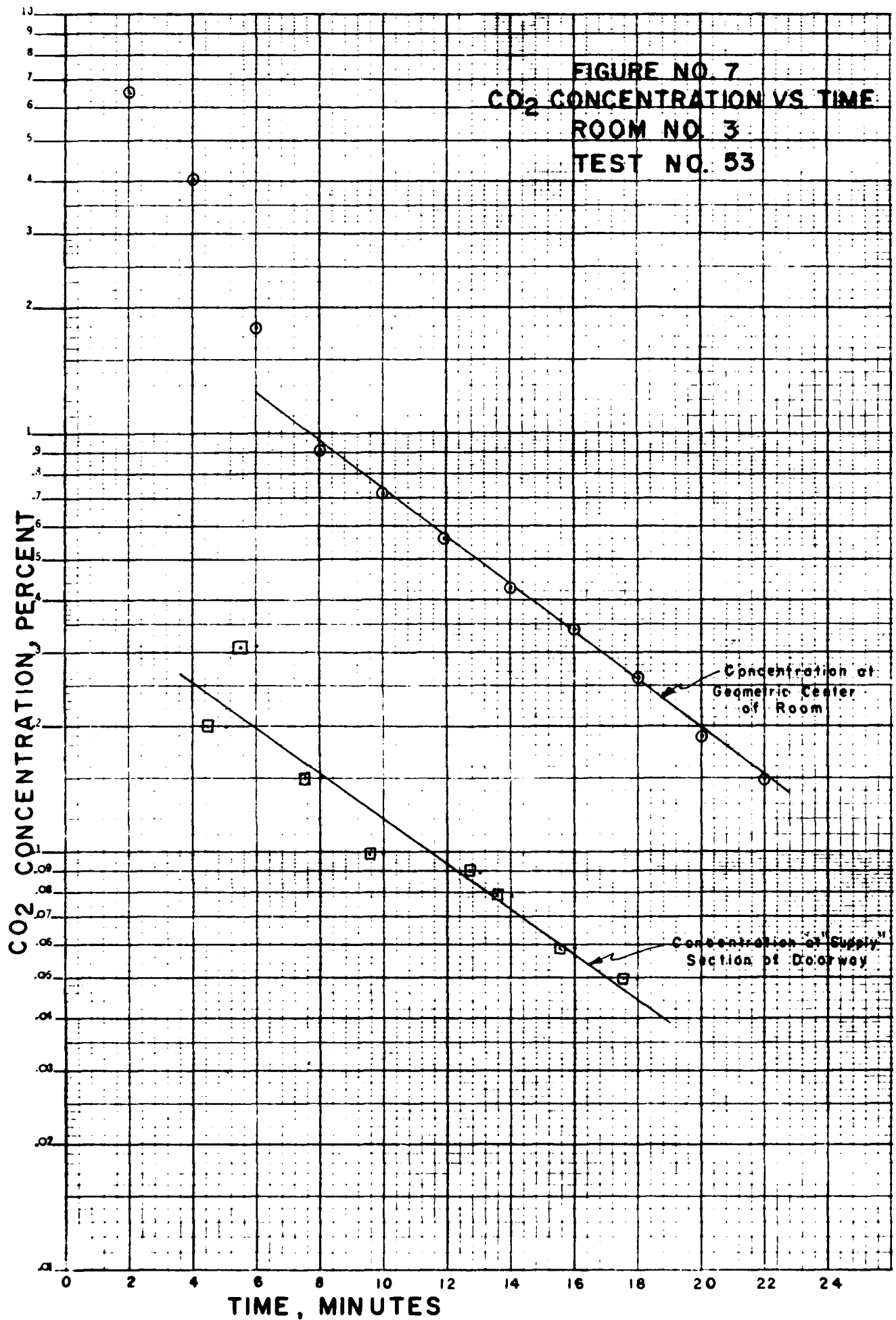
$$\ln C = \ln C_0 - nt$$

From a plot of the logarithm of percent concentration versus time, the slope of the decay curve could be determined as a measure of the number of air changes per unit time. A typical decay curve on semi-log coordinates is shown on Figure 7 which follows, for a test of Room 3. From this curve, an air change rate, "n" of 0.13 per minute is obtained. Considering the free volume of Room 3, 1413 cubic feet, it can be seen that an air flow through the door, of (n)(V<sub>3</sub>), or 184 cubic feet per minute, occurred. Since the number of occupants in Room 3 is 19, a per capita ventilation rate of 9.8 cfm is inferred.

A complication exists however. The differential equation whose solution is graphically represented by the plot of log concentration versus time, was derived on the assumption that the space under test, having once been charged with the tracer gas, is subsequently ventilated with air which is free of the tracer gas. Such is not the case in the simulated shelter, especially at the lower shelter supply air flow rates where mixing of the inlet and outlet ventilation air streams may occur near the doors to the side rooms. For this reason, it was deemed necessary to determine factors with which to correct the tracer gas air exchange measurements.

Lacking a second carbon dioxide gas analyzer, tests were conducted in which timed samples were taken of the ventilation air supply to the room under test at the same time that the CO<sub>2</sub> analyzer was continuously monitoring the gas concentration in the room. This latter was assumed, and later shown, to represent also the CO<sub>2</sub> concentration in the room exhaust air stream. At the end of the determination, the samples of supply air to the

FIGURE NO. 7  
CO<sub>2</sub> CONCENTRATION VS TIME  
ROOM NO. 3  
TEST NO. 53



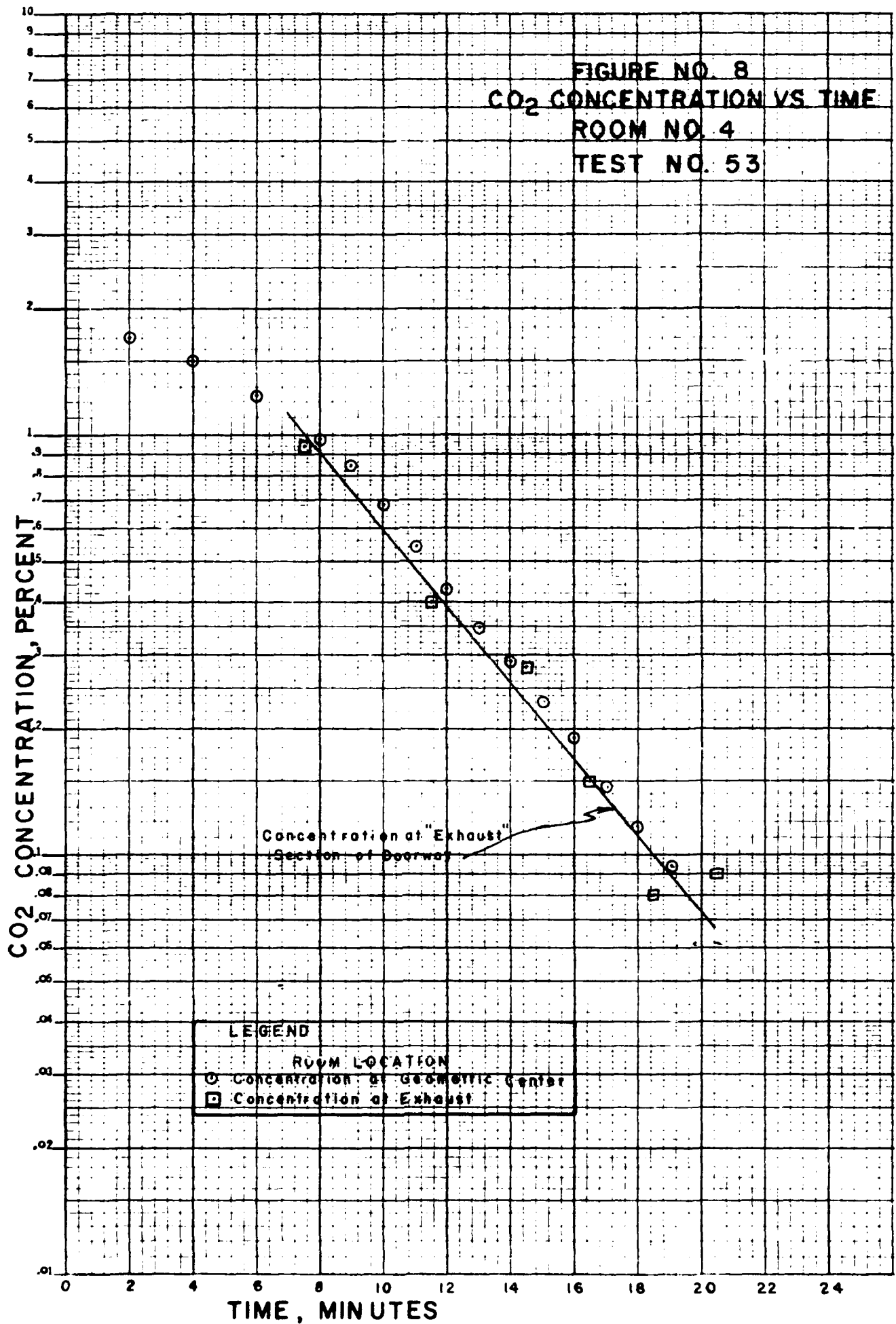
room were successively analyzed to determine their carbon dioxide gas content. A separate determination had been made to ascertain the sampling lag and the time constant of the CO<sub>2</sub> analyzer and with this information, the concentration of CO<sub>2</sub> gas in the supply air stream could be placed in the correct time relationship with that of the exhaust stream. A typical set of measurements is shown in corrected time relationship as the lower curve of Figure 7.

Mathematically, the contamination of the supply air stream with the tracer gas can be taken into account by dividing the number of air changes per unit time by unity less the ratio of CO<sub>2</sub> concentration in supply air, to CO<sub>2</sub> concentration in room (exhaust) air or  $(1 - C_{inlet}/C_{exhaust})$ . This operates to increase the apparent ventilation rate by a factor which was found to vary from 1.4 for low shelter supply air flow rates to 1.17 for the highest rate of 25 cfm per occupant. In other words, the uncorrected value of air changes per unit time is in reality a measure of the "pure air" exchange with the room, "pure" in the sense that it had never been contaminated with the tracer gas. The corrected value of air changes takes into account the fact that other than "pure air" was also entering the side room, i.e., air that already contained some CO<sub>2</sub> and hence by inference, already contained some of the heat and moisture released by the occupants of the side rooms. For the example shown on Figure 7, the ratio  $C_{inlet}/C_{exhaust}$  is 0.16, the corrected value of ventilation is  $184/0.84$  or 219 cubic feet per minute.

Still another complicating factor needed to be taken into account. There was no assurance that all of the air (CO<sub>2</sub> contaminated and CO<sub>2</sub> free) which entered the doorway of the side room as an inlet air current, actually penetrated into this room and took some part in its ventilation. The possibility existed that some of this stream exited almost immediately, having entered the room only a short distance. This possibility was tested in experiments in which timed samples were taken at both the lower (inlet) and upper (outlet) areas of the doors to Rooms 3 and 4. Subsequent analysis of these samples and comparison with continuous data from the center of the room indicated that during periods of natural ventilation, (i.e., Punkahs not in operation) the exhaust air had essentially the same gas concentration as that of the air in the center of the room indicating that all of the supply air stream had penetrated well into the room and taken some part in its ventilation. Had there been significant short circuiting of this air stream, the exhaust samples would have been measurably diluted as compared to the room air CO<sub>2</sub> concentration. A line, indicating the concentrations of the exhaust samples is shown on Figure 8, and can be seen to be almost coincident with the room decay curve.

When Punkahs were employed, there was apparent short circuiting of the inlet air to the outlet stream. There was a strong velocity component down and along the Punkah on the power stroke which mixed air from the upper portion of the doorway with the flow into the room near the floor. For this reason, the tracer gas technique is not regarded as reliable when attempted at times when the Punkahs were in operation. Further, there was extensive mixing of inlet and exhaust air just outside the doorways of Rooms 3 and 4 leading to correction values for air changes of the order of 0.6 to 0.2; i.e., the observed ventilation rates should have been multiplied by 1.7 to 5 respectively. Under such conditions, the accuracy of the tracer gas technique is open to serious question.

FIGURE NO. 8  
CO<sub>2</sub> CONCENTRATION VS TIME  
ROOM NO. 4  
TEST NO. 53



## DISCUSSION AND RESULTS

The results obtained during the ventilation studies of the adiabatic simulated compartmented shelter are presented in the figures and tables which follow, together with some comments as to their significance. The overall arrangement of this material is as follows: Environmental Responses to Steady-State and Diurnal Tests, Steady-State Responses of Side Rooms, Air Flow Patterns, Shelter Micro-Environmental Patterns, Tracer Gas Measurements, and the Package Ventilation Kit. Detailed data on which the following curves and plots are based are contained in Appendix B. An Index to Shelter Configurations and Test Numbers is given by Table V.

Environmental Responses to Steady-State and Diurnal Tests are presented chronologically on the six sections of Figure 9, together with the supply conditions which brought about these responses. The response of the shelter during each of the 65 tests depicted has been broken down to show the average environmental conditions existing in each shelter room, as determined from measurements of temperature-humidity sensing instruments. The number of instruments in each room and their location are shown on Figure 6, schematics of the Ventilation Configurations and their modifications are shown on Figure 3. An average shelter effective temperature may be obtained at any time by weighting the individual room average effective temperatures as follows, Room 1 - 35/112; Room 2 - 45/112; Room 3 - 19/112; Room 4 - 13/112.

In general, interpretation of Figure 9 should be based on examination of the last day of a diurnal and the last two to three hours of a steady-state test. If inspection of the plots of supply air conditions reveals a period when temperature control was faulty, this fact should be considered.

Evaluation of responses to Ventilation Configurations 1-N, and 1-P were conducted during the period April 22 - May 8 and also from June 12 through 15. The latter period should be referred to for a presentation of diurnal tests, the diurnal test first conducted (April 22-24) was plagued with start-up difficulties, and in addition, as explained in the section on EQUIPMENT, was conducted with a metabolic water evaporation rate based on the shelter average effective temperature, rather than with individual water rates to each room based on the temperature in that room. Control problems are evident from the supply air plots, and there was a shelter fan power failure on April 24.

The responses to the various steady-state tests may be interpreted more readily by noting that steady-state tests were conducted at maximum (93 F - Dry Bulb), average (84.6 F - Dry Bulb) and minimum (76 F - Dry Bulb) supply air conditions, with a constant dew point of 72 F. The nearly horizontal lines depicting these temperatures are apparent. Examination of the curves indicates that for maximum temperature supply air conditions, no air flow was adequate to make all shelter rooms habitable. At average supply air conditions, the highest air flow (22.5 cfm) was not adequate when natural ventilation was employed (Test 9) but was adequate when Punkahs were used (Test 21). With Punkahs, a flow rate of 18 cfm of air at average conditions was also adequate (Test 18). For supply air furnished at the minimum conditions, 18 cfm was adequate without Punkahs (Test 7) and 10.5 cfm with Punkahs (Test 22).

TABLE V  
Index to Shelter Configuration and Test Numbers  
Adiabatic Simulated Protective Shelter  
P.S.D.C., Fort Belvoir, Virginia

<u>Test Number</u>	<u>Configuration Number *</u>	<u>Shelter Ventilation Rate (CFM/Occupant)</u>	<u>Shelter Supply Condition **</u>
1	1-N	13.5	Diurnal Cycle
2	1-N	13.5	Minimum
3	1-N	13.5	Average
4	1-N	13.5	Maximum
5	1-N	18.0	Maximum
6	1-N	18.0	Average
7	1-N	13.0	Minimum
8	1-N	22.5	Maximum
9	1-N	22.5	Average
10	1-N	23.0	Average
11	1-N	8.0	Minimum
12	1-N	10.5	Average
13	1-N	10.5	Minimum
14	1-P	10.5	Average
15	1-P	15.0	Average
16	1-P	13.5	Minimum
17	1-P	13.5	Maximum
18	1-P	18.0	Average
19	1-P	19.0	Minimum
20	1-P	22.5	Maximum
21	1-P	22.5	Average
22	1-P	10.5	Minimum
23	1-P	18.0	Maximum
24	2-N	13.5	Diurnal
25	2-N	13.5	Average

TABLE V, CONTINUED

<u>Test Number</u>	<u>Configuration Number *</u>	<u>Shelter Ventilation Rate (CFM/Occupant)</u>	<u>Shelter Supply Condition **</u>
26	2-N	13.5	Minimum
27	2-P	13.5	Minimum
28	2-P	13.5	Average
29	2-P	13.5	Maximum
30	2-N	13.5	Maximum
31	2-N	18.0	Maximum
32	2-P	18.0	Maximum
33	2-P	18.0	Average
34	2-N	18.0	Average
35	2-N	18.0	Minimum
36	2-P	18.0	Minimum
37	2-P	18.0	Average
38	2-P	10.5	Minimum
39	2-N	10.5	Minimum
40	2-N	10.5	Average
41	2-P	10.5	Average
42	2-P	8.0	Minimum
43	2-N	8.0	Minimum
44	2-N	22.1	Maximum
45	2-P	22.1	Maximum
46	2-N	25.0	Diurnal
47	2-B	25.0	Diurnal
48	2-PB	25.0	Diurnal
49	2-P	25.0	Diurnal
50	2-P	13.5	Diurnal

TABLE V, CONTINUED

<u>Test Number</u>	<u>Configuration Number *</u>	<u>Shelter Ventilation Rate (CFM/Occupant)</u>	<u>Shelter Supply Condition **</u>
51	2-N	22.5	Average
52	2-P	22.5	Average
53	1-N	25.0	Diurnal
54	1-N	8.0	Minimum
55	3-N	25.0	Diurnal
56	3-N	18.0	Average
57	3-N	18.0	Average
58	3-N	18.0	Minimum
59	3-N	10.5	Minimum
60	3-N	10.5	Average
61	3-N	13.5	Maximum
62	3-N	13.5	Average
63	3-N	13.5	Minimum
64	3-N	8.0	Minimum
65	3-N	13.5	Diurnal

\* Configuration numbers correspond to shelter configurations as shown on Figure 3.

\*\* For "Diurnal" entries the supply air conditions correspond to "high design" day temperatures as shown on Figure No. 1; for other entries the following conditions were supplied constantly: 1. Maximum - 93 F (Dry Bulb) and 72 F (Dew Point), 2. Average - 84.6 F (Dry Bulb) and 72 F (Dew Point), 3. Minimum - 76 F (Dry Bulb) and 72 F (Dew Point).

For succeeding portions of Figure 9, only the diurnal-cycle responses will be considered. For the steady-state data depicted, Figure 9 serves mainly as a chronological plot from which the location and validity of data used in the construction of other Figures may be determined.

During the evaluation of Ventilation Configuration 2, six diurnal-cycle tests were made, two at a shelter ventilation rate of 13.5 cfm per occupant which was estimated to produce an average shelter effective temperature of 85 F, and four at a ventilation rate of 25 cfm per occupant which was predicted to produce a maximum shelter effective temperature of 85 F. In the predictions of shelter response, it should be noted that only the overall shelter response could be estimated, the responses of the individual rooms which were to make up the shelter could be determined only by experiment.

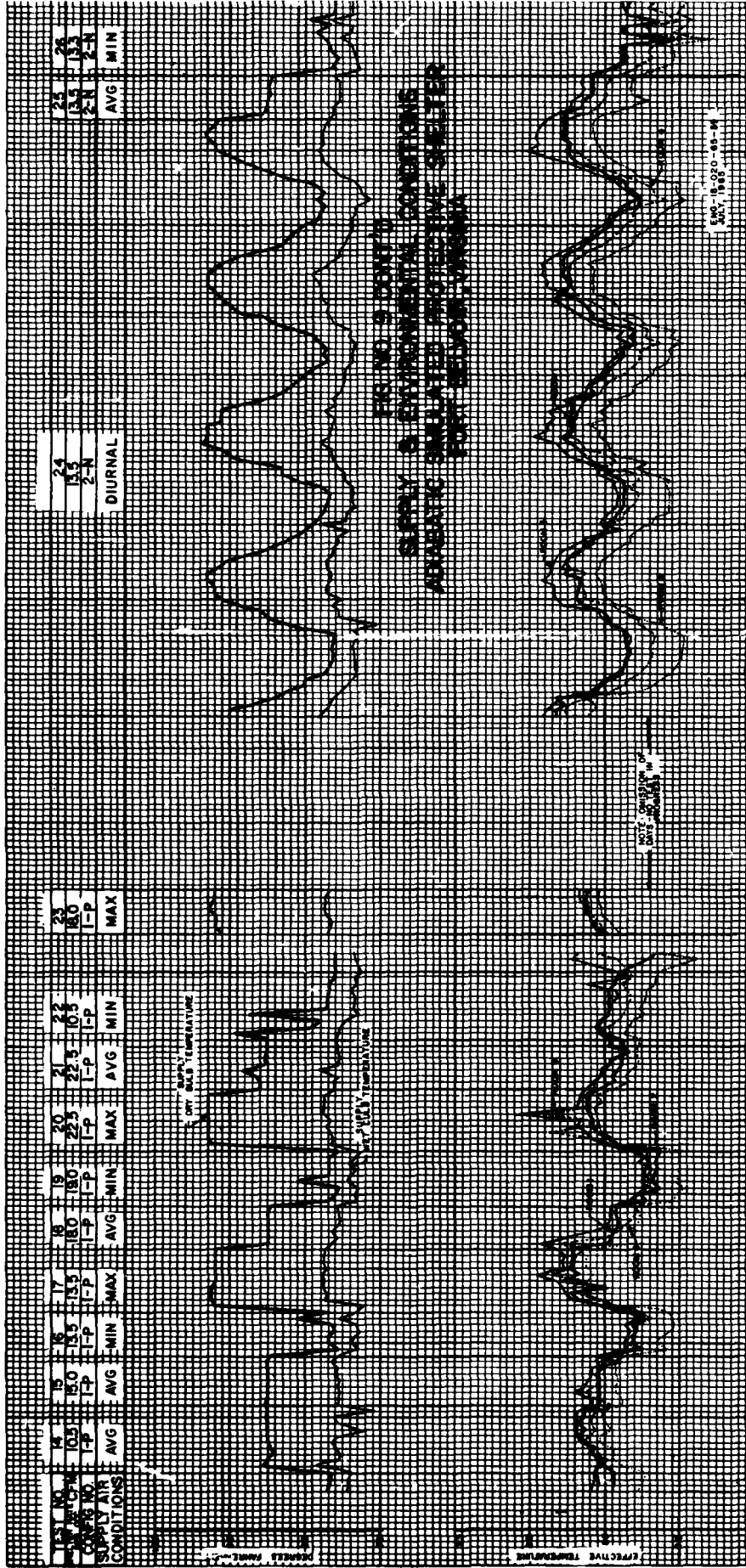
When the shelter was ventilated at 13.5 cfm (Test 24) the average temperatures of the individual rooms were Room 1 - 85.7 F; Room 2 - 83.2 F; Room 3 - 86.6 F, and Room 4 - 85.0 F. For a criterion of 85.0 F average effective temperature, Rooms 1 and 3 would have been unuseable. The shelter average effective temperature was 84.7 F, close to the 85.0 F predicted. At 25 cfm per occupant (Test 46), Rooms 1, 3, and 4 show peak effective temperatures above 85 F. The employment of an air directing baffle (Test 47) actually made conditions worse in Rooms 3 and 4 for reasons to be discussed later. The employment of Punkahs and/or baffles in Tests 48 and 49 greatly improved environmental conditions in Rooms 3 and 4 without material change in Rooms 1 and 2. During these tests, Room 2 (which was the air inlet in this Configuration) was the only space which never exceeded an 85.0 F effective temperature, but the excess over 85.0 F for the other rooms was slight and for only a few hours at a time. However, a strict adherence to a maximum of 85.0 F effective temperature as a criterion would rule out all but Room 2 for extended occupancy. The increase in ventilation air which would be necessary to further reduce the shelter response cannot readily be estimated.

The diurnal response of the shelter to a ventilation test at 13.5 cfm per occupant while Punkahs were employed was investigated in Test 50. The average shelter effective temperature for a twenty-four hour period was 84.1 F, somewhat lower than the predicted value of 85.0. The 24 hour averages for the individual rooms were: Room 1 - 85.3; Room 2 - 82.6; Room 3 - 85.0; and Room 4 - 84.4. Thus, it is seen that almost the entire shelter is habitable if the criterion of 85.0 F average effective temperature is employed.

A diurnal test with Ventilation Configuration 1-N (without Punkahs) was conducted at 25 cfm per occupant as Test 53. For a criterion of maximum effective temperature of 85.0 F, Rooms 1, 3, 4 were all unuseable.

Two diurnal tests were conducted with Ventilation Configuration 3, one at 13.5 cfm per occupant to limit average response to 85 F, one at 25 cfm per occupant to limit maximum response to 85 F. In Test 55 (25 cfm), only Room 2 exceeded 85.0 F effective temperature, and this for seven of the 24 hours. In the 13.5 cfm Test No. 65 (13.5 cfm), the overall shelter average effective temperature was 83.9 F, while the individual rooms averaged as follows: Room 1 - 83.7; Room 2 - 85.7; Room 3 - 81.9; and Room 4 - 80.5. Only Room 2 exceeds the criterion of 85 F average effective temperature.





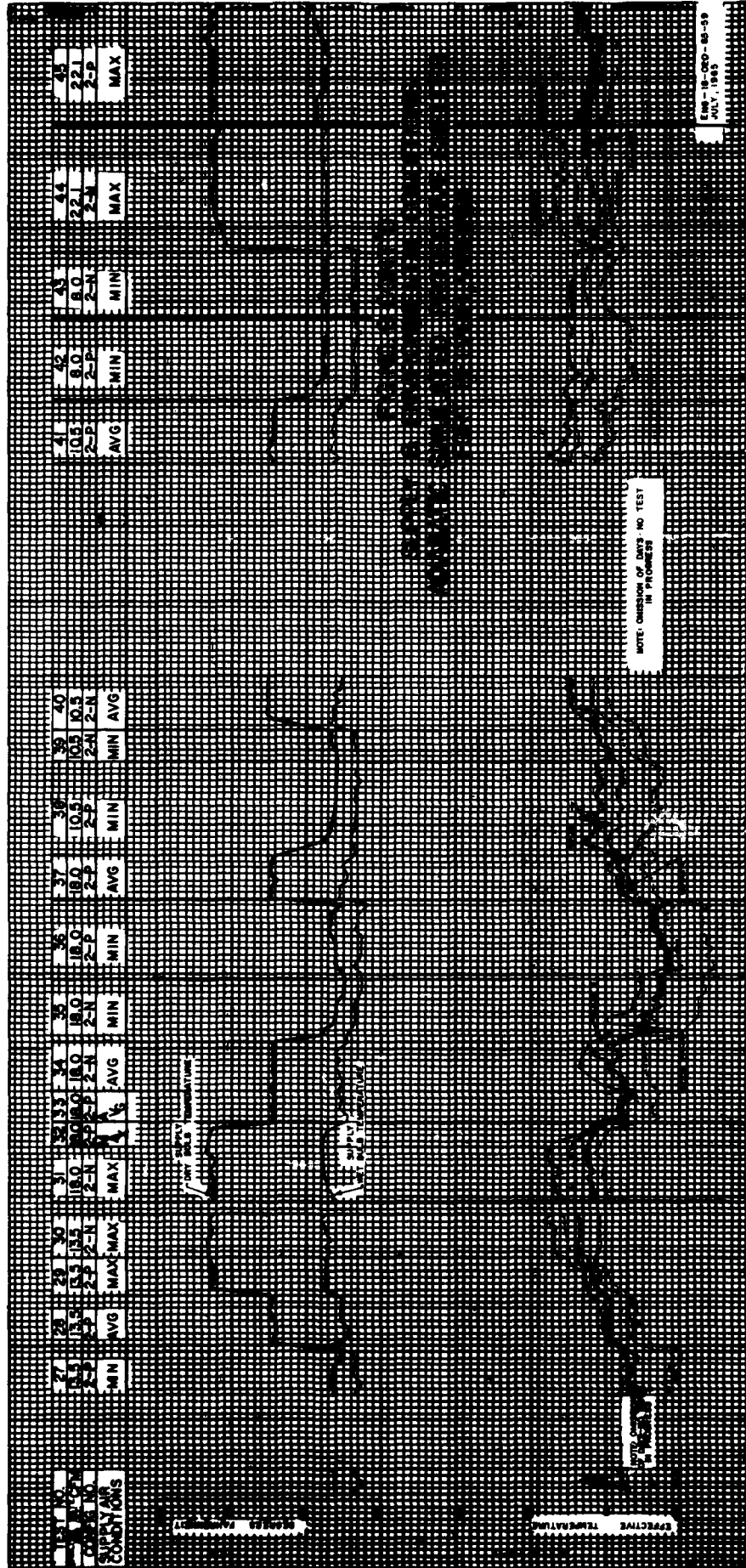
TEST NO.	14	15	16	17	18	19	20	21	22	23
WATER TEMP	150	150	155	155	180	180	225	225	225	180
AIR TEMP	1-P	1-P	1-P	1-P	1-P	1-P	1-P	1-P	1-P	1-P
SUPPLY AIR	AVG	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
CONDITIONS										

24	25
155	155
2-N	2-N
DIURNAL	AVG MIN

FIG. NO. 9 CONT'D  
SUPPLY & ENVIRONMENTAL CONDITIONS  
AUTOMATIC BALLASTED PROTECTIVE SHELTER  
FOR HELICOPTER LANDING

WATER TEMPERATURE

AIR TEMPERATURE



TEST NO.  
27  
28  
29  
30  
31  
32  
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34  
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36  
37  
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39  
40  
41  
42  
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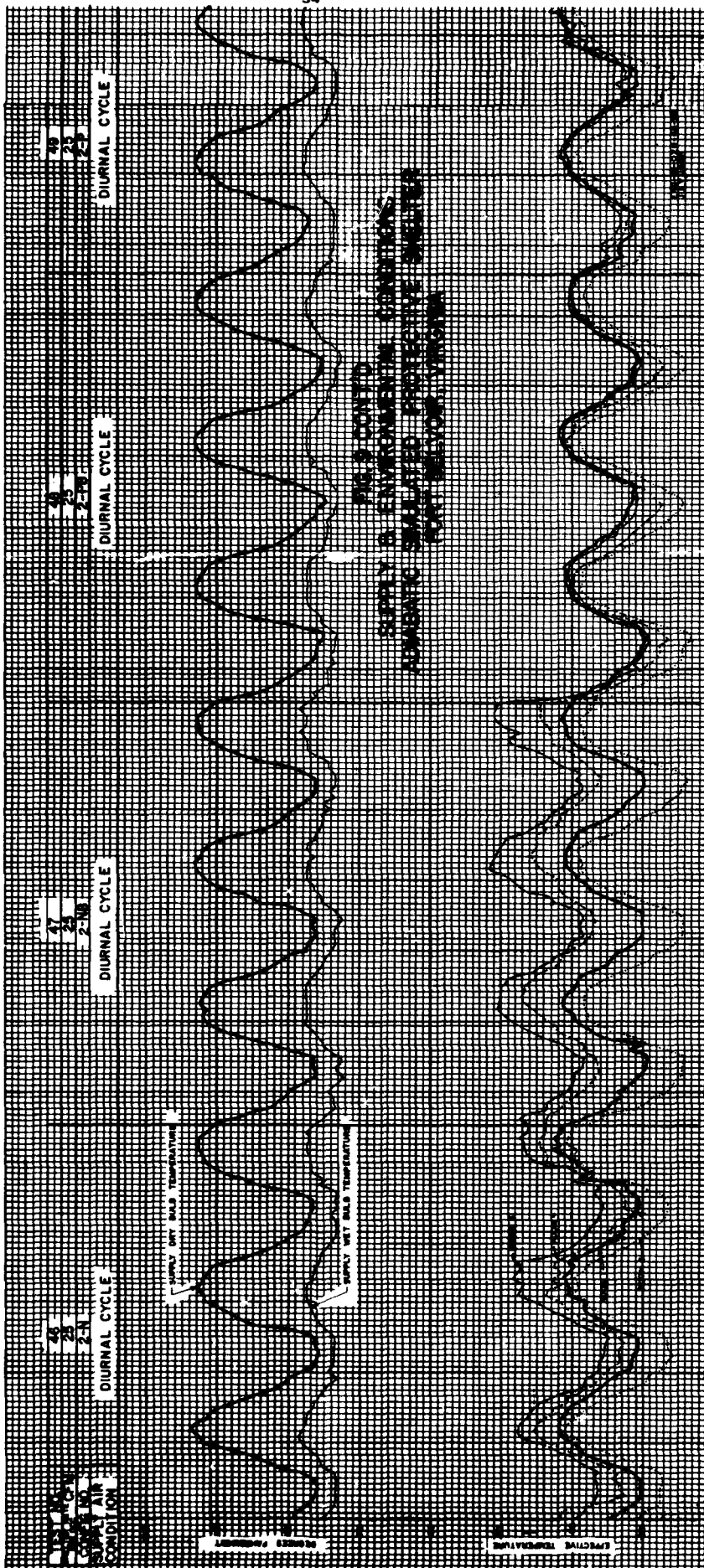
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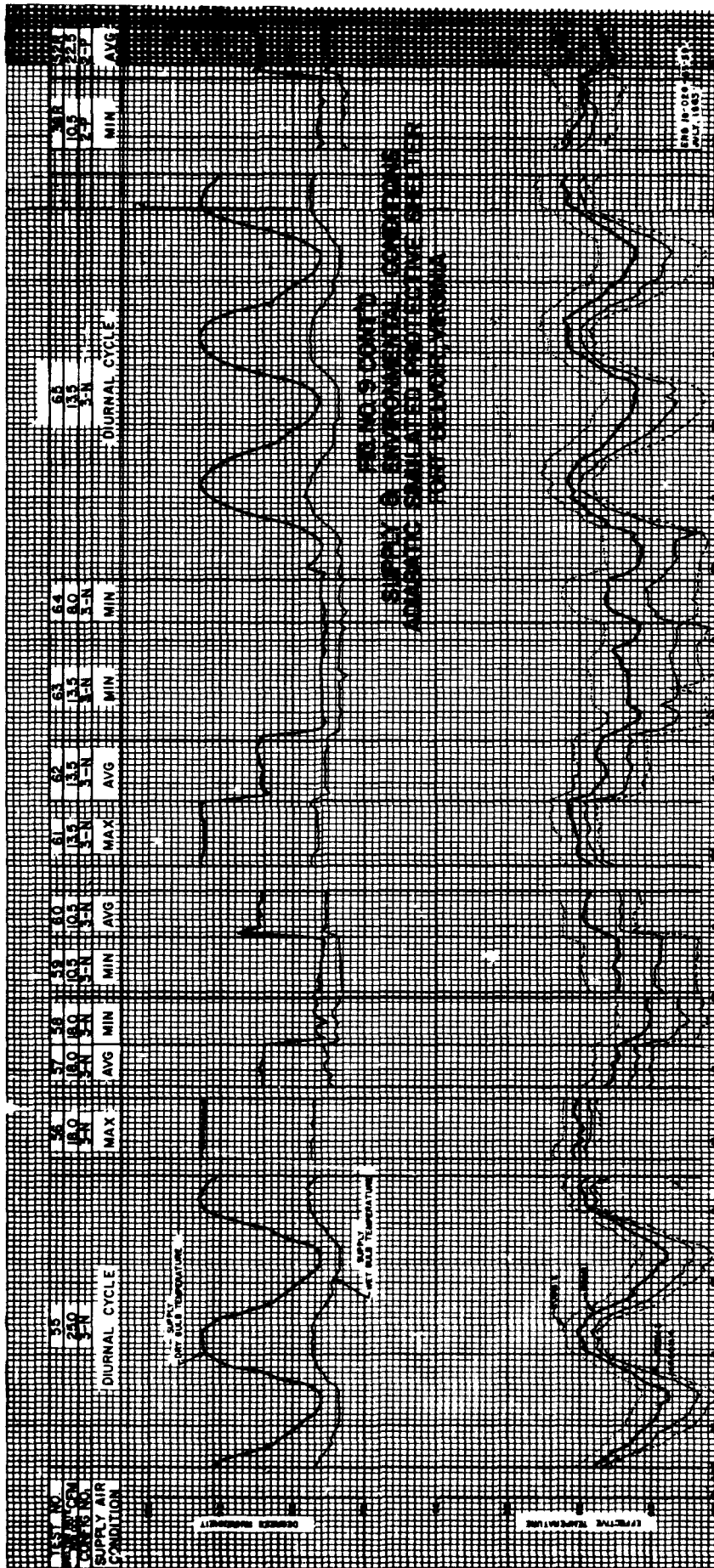
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TEMP-18-000-85-59  
JULY, 1965







The Steady-State Responses of the Side Rooms which are shown chronologically on Figure 9, are collected and presented as a function of shelter ventilation rate on Figures 10 through 14. Only the tests depicting responses to shelter ventilation at the "average" design day condition of 84.6 F dry bulb temperature and 72.0 F dew point temperature are shown; responses to steady-state ventilation tests employing air at the maximum and minimum conditions of the diurnal cycle produced curves of similar shape.

The response of the four rooms to different air flows, for the configuration in which the PVK was employed as a supply fan is shown on Figure 10. The salient feature to be noted is the non-linear response of the side rooms to changes in the shelter ventilation rate. In the range of ventilation rates from 10 to 15 cfm per occupant, the reduction in effective temperature in the side Rooms 3 and 4 is as great or greater than for any other shelter area, being about 2 degrees drop in effective temperature for a 5 cfm increase in ventilation rate. At shelter ventilation rates of from 14 to 16 cfm, the response curves for Rooms 3 and 4 become quickly asymptotic to the ventilation-rate axis, i.e., no further improvement in effective temperature is accomplished by increases in ventilation rate. For a criterion of 85 F average effective temperature, neither room provides a useable environment at any ventilation rate tested.

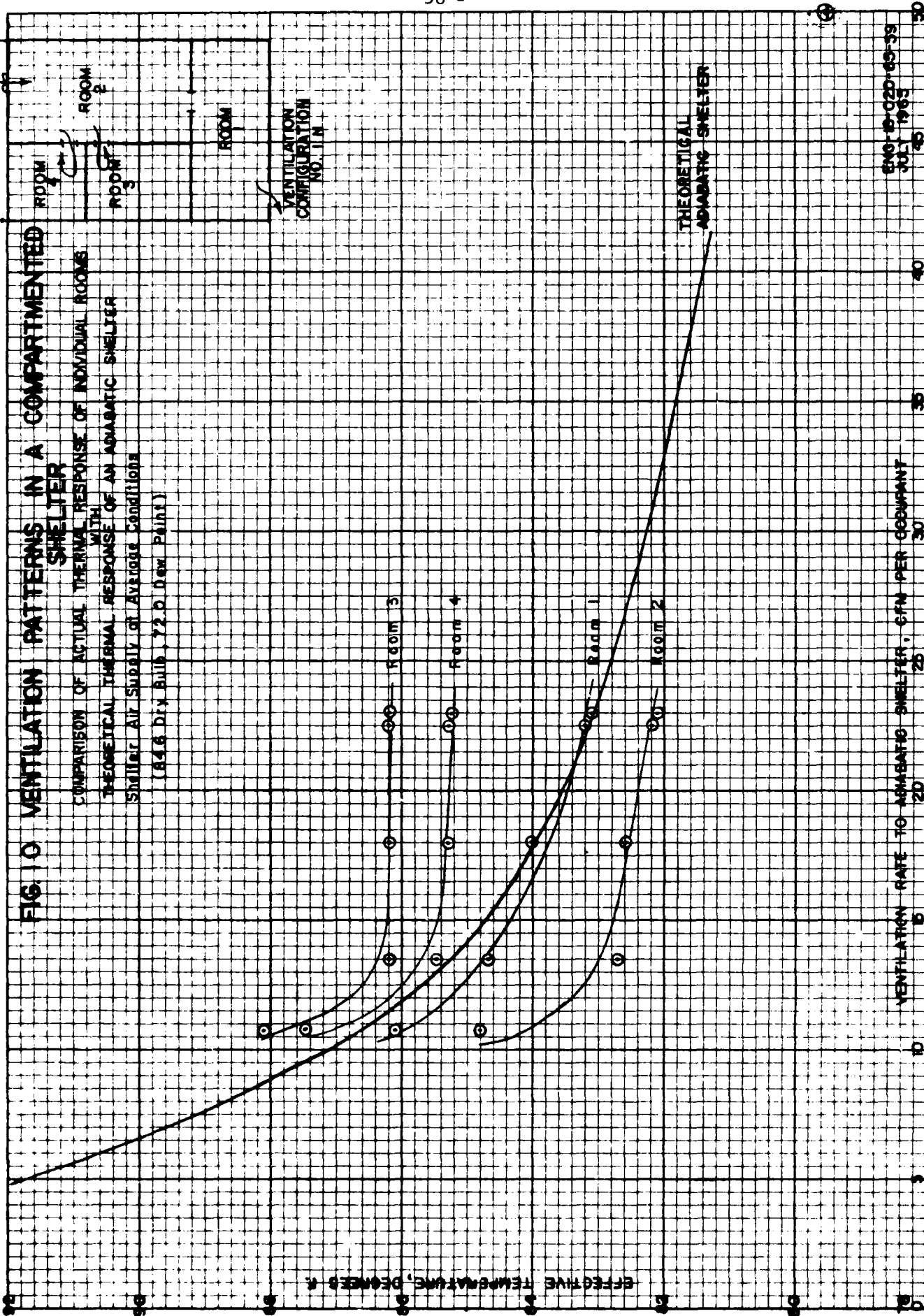
It is postulated that the ventilation of the side rooms is almost entirely accomplished by thermal currents (stack effects) and that the air supply to the vicinity of the doorways merely promotes these effects by maintaining a suitable environment at that point, but cannot measurably increase the velocity of the thermal currents within the room. Further, it appears that the volume of ventilation air to these side rooms is affected by doorway size, thus Room 3 with the same size doorway as Room 4, always exhibits higher effective temperatures, because it contains more people (Simocs). This supposition is supported by air exchange measurements to be discussed later.

The behavior of Room 1 is of interest, as it appears to follow the postulated adiabatic response curve quite well. This might be expected, since it is the "exhaust" of the shelter. Room 2, on the contrary, is the "inlet", and since it receives all of the shelter ventilation air, and receives it first, is in effect being provided with much better ventilation than any other area of the shelter. However, its performance curve, even were it shifted to higher ventilation rates, cannot be made to fit the adiabatic curve. This is doubtless due to the influence of the side rooms at the lower air flow rates. At the higher rates, the side rooms are no longer responding to changes in ventilation rate and the curve for Room 2 approximates the behavior of an adiabatic shelter at very high air flow rates.

When Punkahs were operated in conjunction with Ventilation Configuration 1, the results, as shown on Figure 11, were favorable. Using as a criterion, an average effective temperature of 85 F, Room 4 became habitable at a ventilation rate of 12.5 cfm and Room 3 at 16 cfm. Further, the "spread" in effective temperatures which had been four degrees without the Punkahs was reduced to two degrees when these devices were employed. If a ventilation rate of 16 cfm per occupant is selected as adequate, since it makes all the rooms habitable when Punkahs are em-

FIG 10 VENTILATION PATTERNS IN A COMPARTMENTED SHELTER

COMPARISON OF ACTUAL THERMAL RESPONSE OF INDIVIDUAL ROOMS WITH THEORETICAL THERMAL RESPONSE OF AN ADIABATIC SHELTER  
Shelter Air Supply at Average Conditions  
(84.6 Dry Bulb, 72.0 Dew Point)



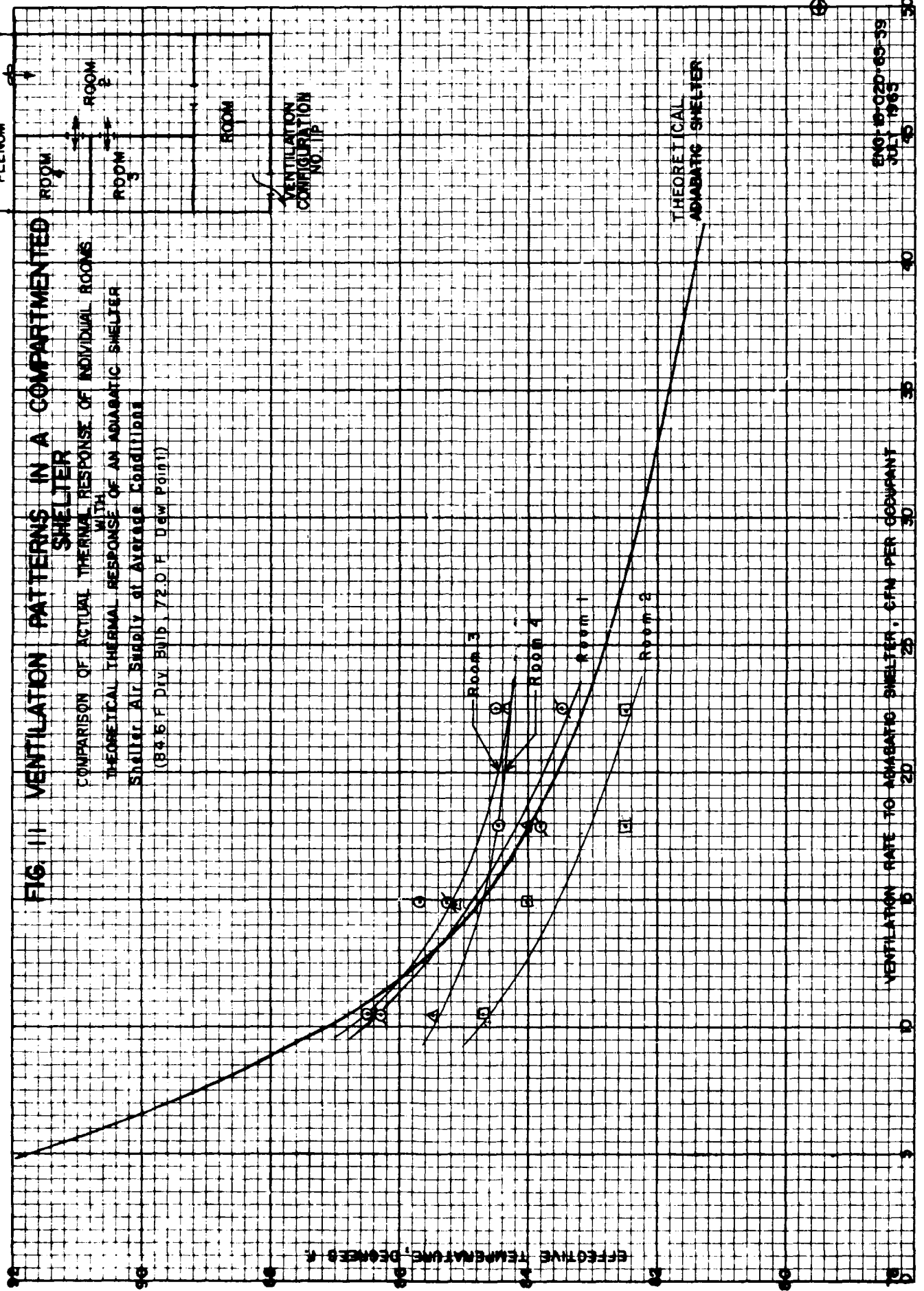
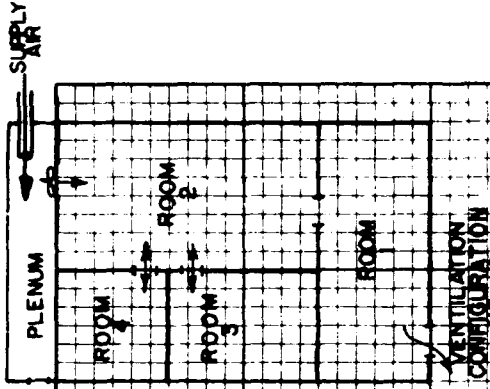
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VENTILATION RATE TO ADIABATIC SHELTER, CFM PER OCCUPANT

10 20 30

FIG. III VENTILATION PATTERNS IN A COMPARTMENTED SHELTER

COMPARISON OF ACTUAL THERMAL RESPONSE OF INDIVIDUAL ROOMS WITH  
THEORETICAL THERMAL RESPONSE OF AN ADIABATIC SHELTER  
Shelter Air Supply at Average Conditions  
(84.6°F Dry Bulb, 72.0°F Dew Point)



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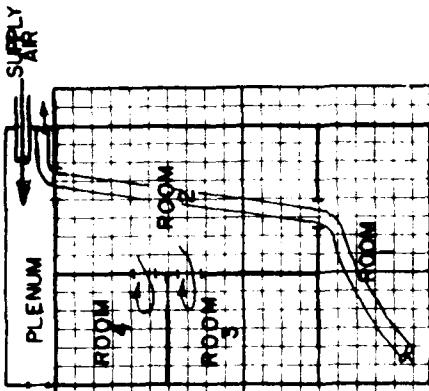
VENTILATION RATE TO ADIABATIC SHELTER, CFM PER OCCUPANT

FIG. 12 VENTILATION PATTERNS IN A COMPARTMENTED SHELTER

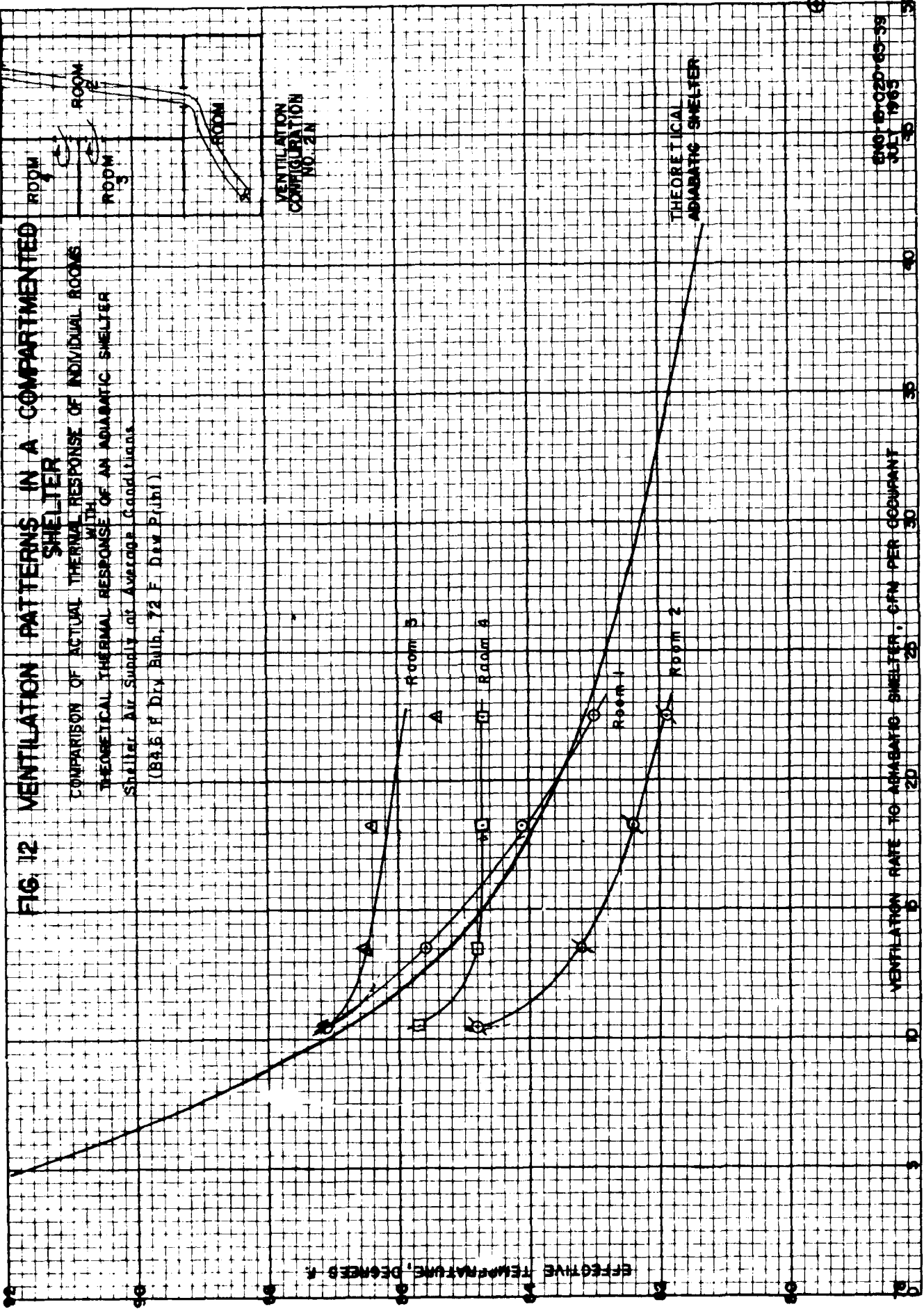
COMPARISON OF ACTUAL THERMAL RESPONSE OF INDIVIDUAL ROOMS WITH THEORETICAL THERMAL RESPONSE OF AN ADIABATIC SHELTER

Shelter Air Supply at Average Conditions

(84.6 F Dry Bulb, 72 F Dew Point)



VENTILATION CONFIGURATION NO. 2A

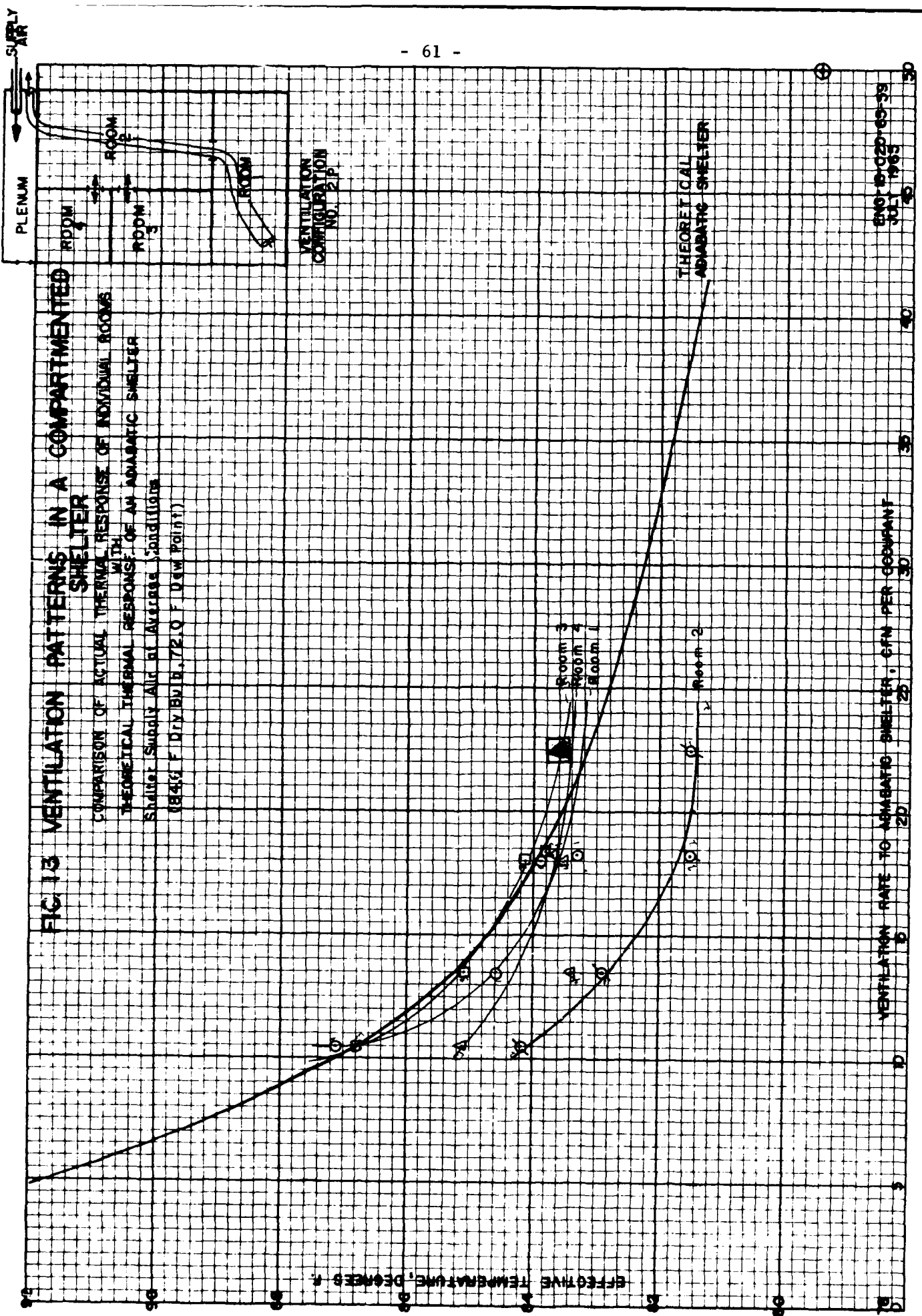


VENTILATION RATE TO ADIABATIC SHELTER, CFM PER OCCUPANT

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FIG 13 VENTILATION PATTERNS IN A COMPARTMENTED SHELTER

COMPARISON OF ACTUAL THERMAL RESPONSE OF INDIVIDUAL ROOMS WITH THEORETICAL THERMAL RESPONSE OF AN ADIABATIC SHELTER  
Shelter Supply Air at Average Conditions  
(84.6 F Dry Bulb, 72.0 F Dew Point)



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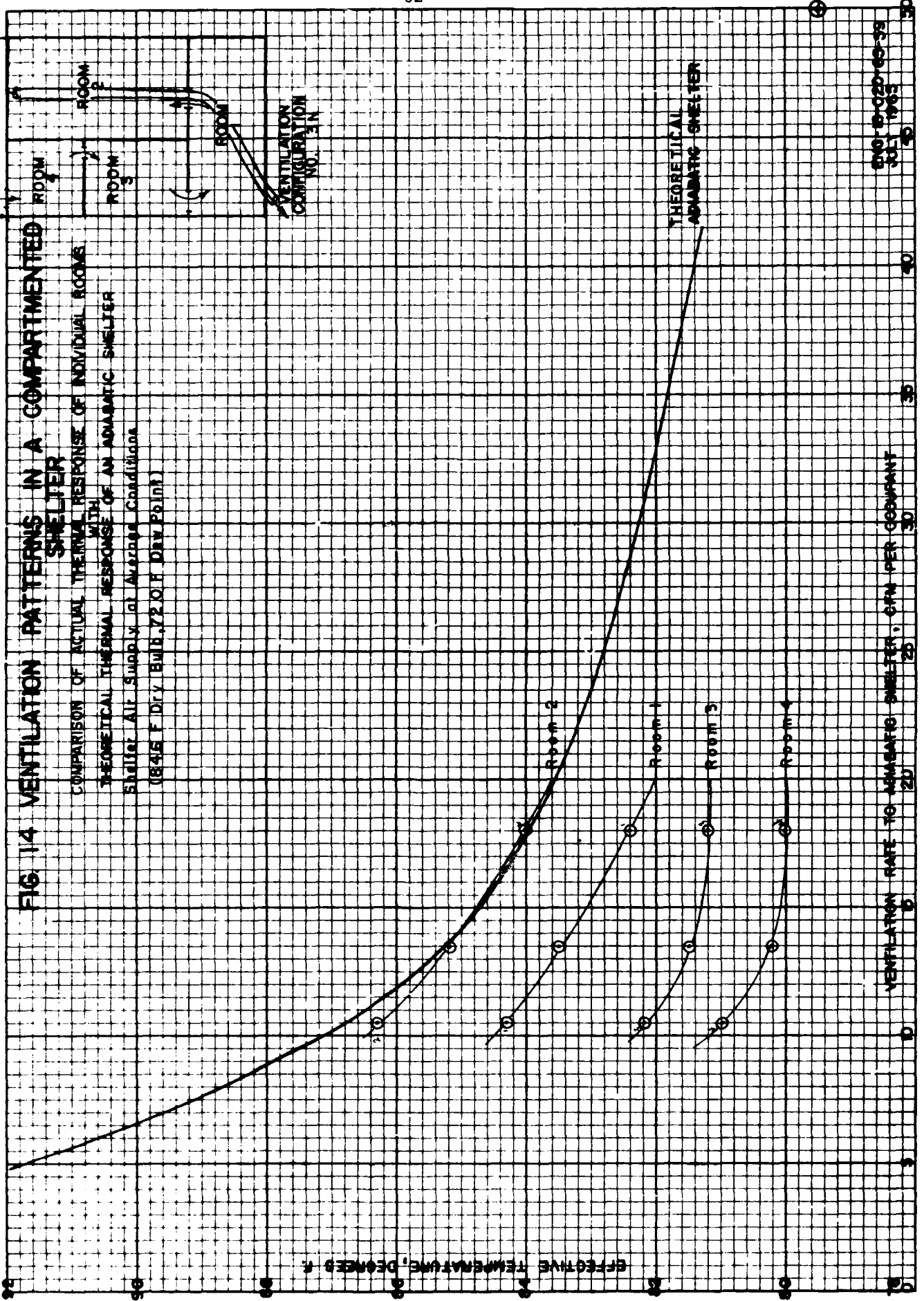
**FIG. 14 VENTILATION PATTERNS IN A COMPARTMENTED SHELTER**

COMPARISON OF ACTUAL THERMAL RESPONSE OF INDIVIDUAL ROOMS WITH

THEORETICAL THERMAL RESPONSE OF AN ADIABATIC SHELTER

Shelter Air Supply at Average Conditions

(84°F Dry Bulb, 72°F Dew Point)



VENTILATION RATE TO ADIABATIC SHELTER, CFM PER OCCUPANT

NO. 15-020-60-58  
JULY 1965

ployed, then the performance with and without Punkahs may be compared at this ventilation rate. The effective temperature in Room 3 dropped 1.2 degrees, in Room 4 it dropped 0.8 degrees, while in Room 1 it increased 0.3 degrees and in Room 2 went up by 0.7 degrees when the switch was made to Punkahs. The overall shelter weighted average effective temperature remained constant at 84.1 F, so that the net result of using the Punkahs was to make useable, two rooms, or shelter space for 32 people which had been unuseable before.

When the individual room performance with and without Punkahs is compared for Ventilation Configuration 2 in which the PVK was used as an exhaust, the same effects are noted as for Configuration 1. The results are shown on Figures 12 and 13. Room 3 is not habitable at any ventilation rate investigated, while Room 4 is marginally habitable (average effective temperature of 84.7 F) at flow rates in excess of about 13.5 cfm per occupant. As in the tests of Configuration 1, the shape of the response curves for Rooms 3 and 4 does not indicate that much change in effective temperature can be achieved after the shelter ventilation rate has reached 14 to 16 cfm per occupant. The employment of Punkahs makes the entire shelter habitable at a ventilation rate of 14 cfm per occupant which is a slight improvement over the 16 cfm per occupant required for Configuration 1.

The room response curves for Ventilation Configuration 3 are shown on Figure 14. As indicated on the Figure, Ventilation Configuration 3 is a ventilation scheme in which each room is supplied in series with the entire ventilation supply for the shelter. As predicted in an earlier publication, this method of ventilation produced the best results for the entire shelter. The "worst" room, in this configuration, Room 2, was adequately ventilated by 14 cfm per occupant as predicted by the adiabatic shelter response curve. All other rooms were "better" in the sense that they achieved lower effective temperatures. The overall shelter average effective temperature for this configuration was 83.2 F as compared to 84.1 for Configuration 1.

The improved environmental conditions resulting from Configuration 3 prompted some theoretical calculations involving ventilation schemes. In the first of these, a shelter in which five persons each receives in succession the entire ventilation air supply, is compared with a shelter in which elaborate air distribution ductwork supplies and removes air for each occupant. It is supposed that each man is in a separate cubicle. The results are tabulated below:

	EXAMPLE I		Effective Temperature	
	<u>Ventilation Rate</u>		<u>Leaving Cubicle</u>	
	Series Flow	Parallel Flow	Series Flow	Parallel Flow
Occupant 1	50 cfm	10 cfm	81.2	87.1
Occupant 2	50 cfm	10 cfm	83.0	87.1
Occupant 3	50 cfm	10 cfm	84.5	87.1
Occupant 4	50 cfm	10 cfm	85.8	87.1
Occupant 5	50 cfm	10 cfm	87.2	87.1

Thus it can be seen that only the last man in the series flow scheme suffers as severe environmental conditions as every man in the parallel flow mode.

In the second calculation, the preferred direction in which to ventilate a shelter is investigated. The arrangement of rooms and the occupancy level of the P.S.D.C. adiabatic simulated shelter are used as a model. A ventilation rate of 18 cfm is selected, since actual data was taken at this ventilation rate. Two series ventilation paths, one beginning in Room 4, the other in Room 2 are investigated.

<u>Room</u>	<u>Number Occupants</u>	EXAMPLE II		Path 2-1-3-4-Exhaust	
		Path 4-3-1-2-Exhaust		Effective Temperatures	
		<u>Actual</u>	<u>Calculated</u>	<u>Calculated</u>	
4	13	80.0	80.4	84.1	
3	19	81.2	81.2	83.6	
1	35	82.4	82.5	83.0	
2	45	<u>84.0</u>	<u>84.1</u>	<u>81.6</u>	
Weighted Average		82.5	82.6	82.6	

From this table, it can be noted that the calculated responses were very close to those actually measured, lending support to the contention that the shelter was truly adiabatic in operation. If it can be surmised

that in the hypothetical shelter, the mixing in each room is good so that no area of a room differs significantly from the room average, then the ventilation Path 4-3-1-2-Exhaust is superior to the Path 2-1-3-4-Exhaust. The first path provides 67 persons with conditions below the average, while the latter only has 45 people below the average conditions. Had the ventilation rate been reduced, so that the average shelter effective temperature had reached 85 F, then any rooms which exceeded this value would have been considered uninhabitable according to the criterion used in this report.

It would not be advisable to generalize on the optimum ventilation path from this one example however. In another theoretical study, a different set of room sizes was considered. For a four room shelter, in which room sizes differed by factors of two, the following effective temperatures were calculated. (The ventilation rate is assumed to be 14.1 cfm per occupant - 1% High Design Day - Washington, D.C.; 84.6 Dry Bulb - 72.0 Dew Point.)

EXAMPLE III

Room	Number Occupants	Path 1-2-3-4-Exhaust	Path 4-3-2-1-Exhaust
		Effective Temperatures Calculated	Calculated
1	10	80.2	85.6
2	20	81.1	84.9
3	40	82.6	84.2
4	80	85.4	83.1

Path 4-3-2-1-Exhaust, i.e., from largest to smallest rooms, results in 140 persons with environmental conditions below 85.0 effective temperature; Path 1-2-3-4-Exhaust, i.e., from smallest to largest rooms only provides useable conditions for 60 persons.

It is believed that other relative room sizes might alter the selection of the optimum ventilation path; thus, in the preceeding example, if Room 4 is split into two rooms, and the air from Room 3 passed successively through them, then Room 4A will develop an effective temperature of 84.3 F while Room 4B will go to 85.6 F. In effect, forty more persons have been placed in a habitable environment by the provision of a partition.

Air Flow Patterns shown on Figures No. 15 and 16 illustrate the main shelter supply stream as it leaves the plenum and enters Room 2. The main stream as seen in Figure 15 leaves the plenum with a velocity component which carries it down along the south side of Room 2. This ventilation pattern then, directs the "fresh" air away from the doorways of the side rooms. In contrast, the main stream as seen in Figure 16 is baffled (note installation of baffle at the doorway from Room 2 to plenum) toward the north side and impinges directly on the doorways of the side rooms. Tests 46, 47, 48, and 49 were conducted to evaluate the effect of these different ventilation patterns.

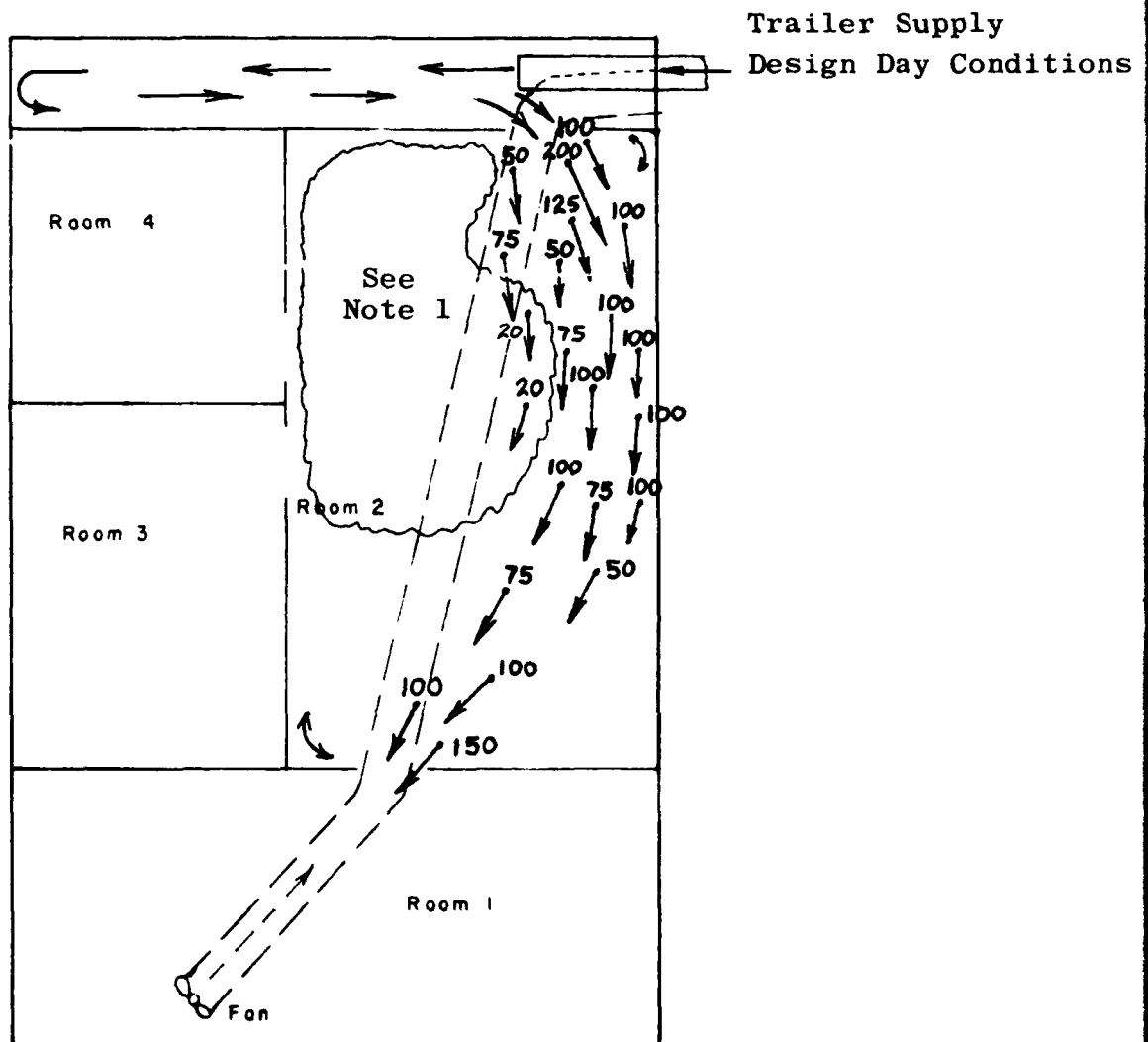
A comparison of the responses of the side rooms for the diurnal Tests 46, 47, 48, and 49 is worthy of discussion. These tests were all conducted at a supply ventilation rate of 25 cfm/occ. but exhibit differing environmental shelter responses because of the application of ventilation adjuncts operating individually (Punkahs) or in combination (Punkahs and baffles). Test 46 was conducted without any ventilation aids and as can be seen in Figure 15 the main shelter supply air stream was directed away from the side rooms. The resulting peak effective temperatures in Rooms 3 and 4 were 88.5 F and 87.2 F, respectively. It was then decided to install a baffle at the shelter supply location and direct the "fresh" air at the doorways of the side rooms. The resulting ventilation pattern for Test 47 can be seen in Figure 16. Despite the fact that relatively high velocity air was impinging directly on the doorways of Rooms 3 and 4, very little "fresh" air was actually penetrating into the rooms. The resulting effect was an increase (rather than the postulated decrease) in environmental conditions which developed during Test 46. For example, Room 3 increased from 88.5 F to 90.5 F effective temperature. The increase in effective temperature can be attributed to the disturbance of the natural ventilation currents (stack effects) which had previously been ventilating the side rooms.

It was then postulated that with the addition of Punkah Pumps the air which was being baffled toward the side rooms (but not entering) could be "forced" to ventilate these isolated areas, and hence improve the severe conditions which had developed during Test 47. Test 48 was then conducted, employing both Punkahs and baffles. The effective temperatures in Rooms 3 and 4 dropped from a peak value of 90.5 F and 87.2 F to 85.5 F and 85.2 F, respectively.

The results of Tests 46, 47, and 48 indicate that baffling alone was not sufficient to provide adequate ventilation of the side rooms, but that the combination of baffles and Punkahs does provide uniform distribution of ventilation air to the side rooms.

In order to obtain a complete evaluation of Configuration 2 (in terms of peak effective temperature in Rooms 3 and 4 at 25 cfm) the baffle was removed (and Test 49 conducted) thereby leaving only the Punkahs as adjuncts. In this manner, it could be ascertained whether or not baffling is advantageous when Punkahs are in operation to insure optimum ventilation distribution to the side room. The resulting peak effective temperatures of Rooms 3 and 4 were essentially unchanged from those of Test 48 and were recorded at 85.9 F and 85.6 F, respectively.

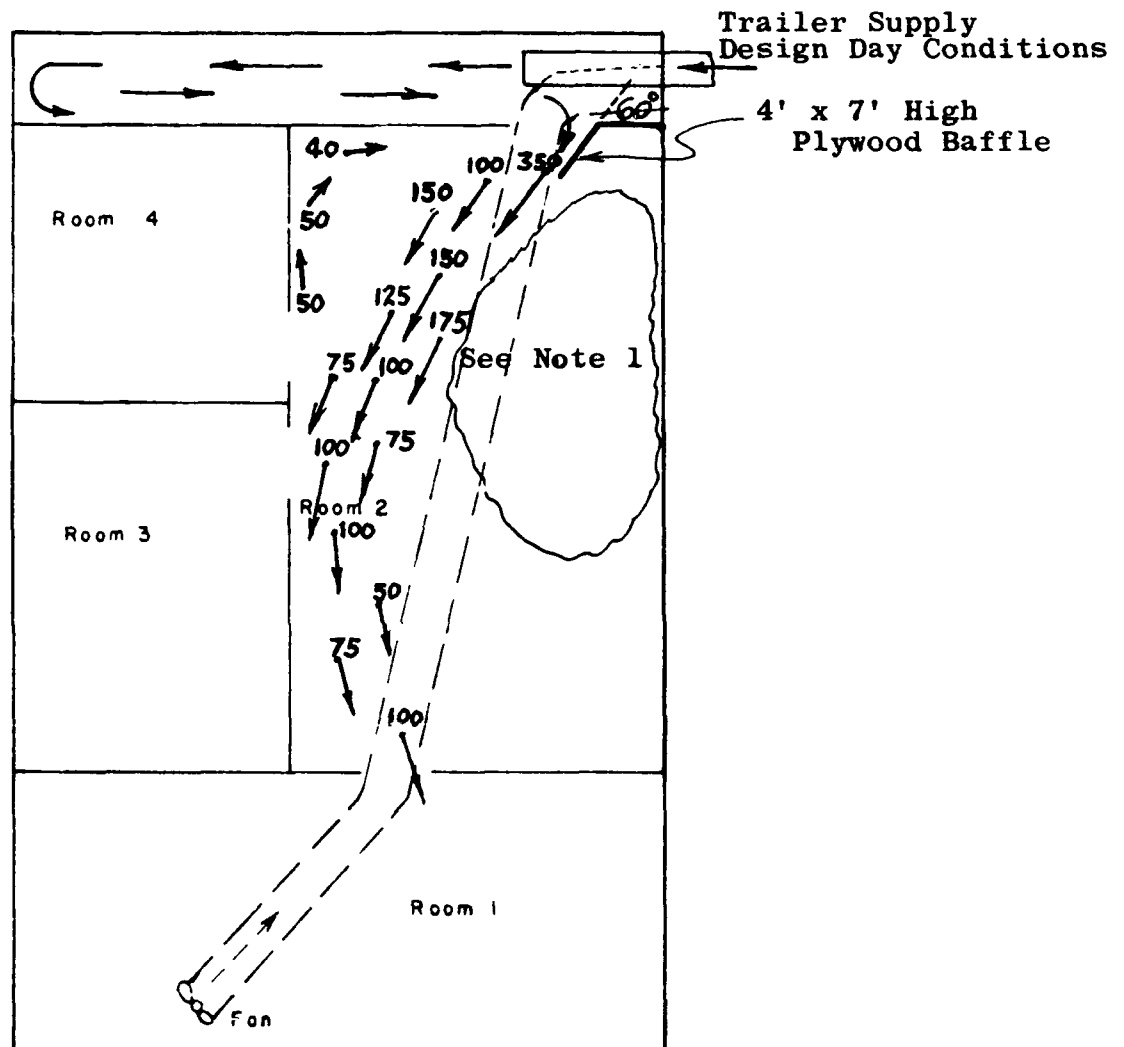
FIG. NO. 15  
MAJOR AIR FLOW PATTERNS IN ROOM 2  
TEST NO. 46  
CONFIGURATION 2-N



NOTE:1 Velocities Enclosed Within Area, Were in General Under 20 fpm in Magnitude and Very Unsteady in Direction.

NOTE 2 Direction of Air Flow was Determined by "Smoke" and the Velocity Magnitude Determined by "Hot Wire" Anemometer (5 feet off floor).

FIG. NO. 16  
MAJOR AIR FLOW PATTERNS IN ROOM 2  
TEST NO. 47  
CONFIGURATION 2-B



NOTE:1 Velocities Enclosed Within Area, Were in General Under 20 fpm in Magnitude and Very Unsteady in Direction.

NOTE:2 Direction of Air Flow was Determined by "Smoke" and the Velocity Magnitude Determined by "Hot Wire" Anemometer (5 feet off floor).

Shelter Micro-Environmental Patterns were investigated and are presented in Figures No. 17, 18, 19, and in Table VI. These include the determination of ventilation rates for Rooms 3 and 4 (based on a heat balance method) and effective temperature variations throughout the shelter for the Configurations tested.

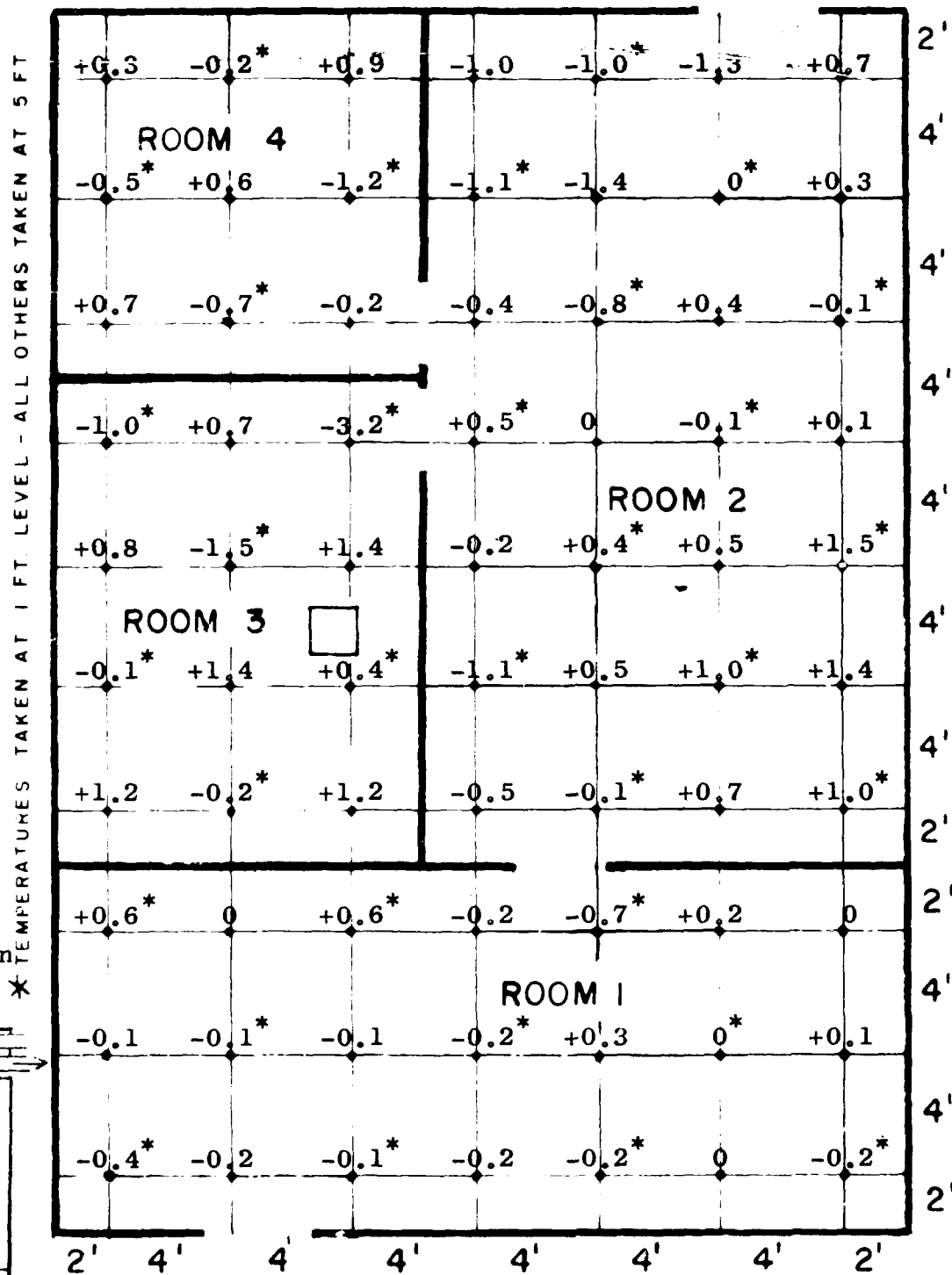
The effectiveness or efficacy of the different Configurations tested can be evaluated in terms of the distribution of the ventilation air. One index to the distribution of this air is the effective temperature variation throughout the test structure. Figures No. 17 and 18 are the results of temperature traverses taken with a battery operated aspirating psychrometer. The average environmental conditions of each room are shown at the top of the figure as well as the average shelter effective temperature. The values shown within the room areas are variations from the average temperature for each individual room. The degree of variation or deviation from the room average for any particular location throughout the room is an indication of a "hot spot" or "cool spot". Additional traverses of the same type as Figures No. 17 and 18 are included in Appendix C for consideration.

From Figure No. 17, it can be seen that "hot spots" and "cool spots" exist within Rooms 3 and 4. For example, plus "+" values (which are indicative of severe locations) are outstanding in all but the doorway corner of Room 4 and minus "-" values (which indicate "cool spots") are present about the supply area.

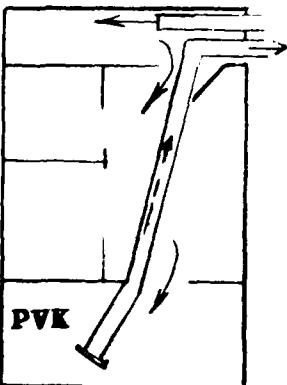
The maximum variation in effective temperatures for Room 4, is 2.1 degrees for Test 47, but with the addition of Punkah Pumps (all other variables being held constant) the maximum variation was only 1 degree as can be seen from Figure 18. Therefore it is inferred that poor distribution exists within the side rooms during periods of "natural" ventilation.

Room 1 shows little change in response when Punkah Pumps are installed. The maximum variation is 1.3 degrees for Test 47 as compared to 1.6 degrees for Test 48.

CONFIGURATION NO. 2-B page 70  
 TEST NO. 47 (Maximum Shelter Response)  
 VENTILATION RATE 25 cfm/occ  
 AVG. SHELTER E.T. 87.0° Fig. No. 17  
 AVG. E.T. OF ROOM 1 86.2  
 2 85.4  
 3 92.0  
 4 88.7



Configuration Key



THE PLUS OR MINUS VALUES SHOWN ARE RELATIVE TO  
 ABSOLUTE MAGNITUDE OF THE AVG. E.T. FOR EACH ROOM.

CONFIGURATION NO. 2-BP

page 71

TEST NO. 48 (Maximum Shelter Response)

VENTILATION RATE 24.5 cfm/occ

AVG. SHELTER E.T. 85.6°

Fig. No. 18

AVG. E.T. OF ROOM

1	86.0
2	85.2
3	86.1
4	85.7

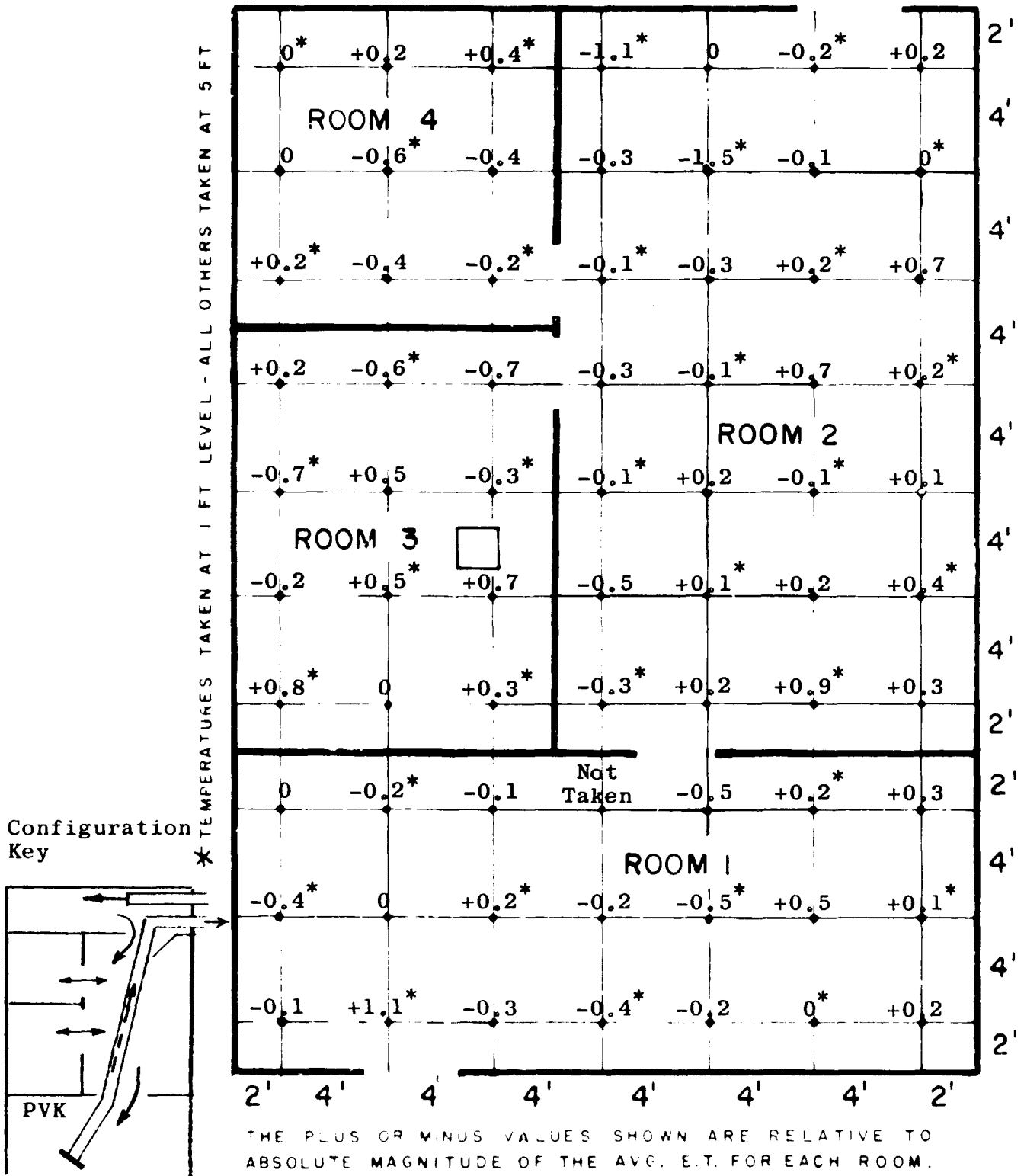


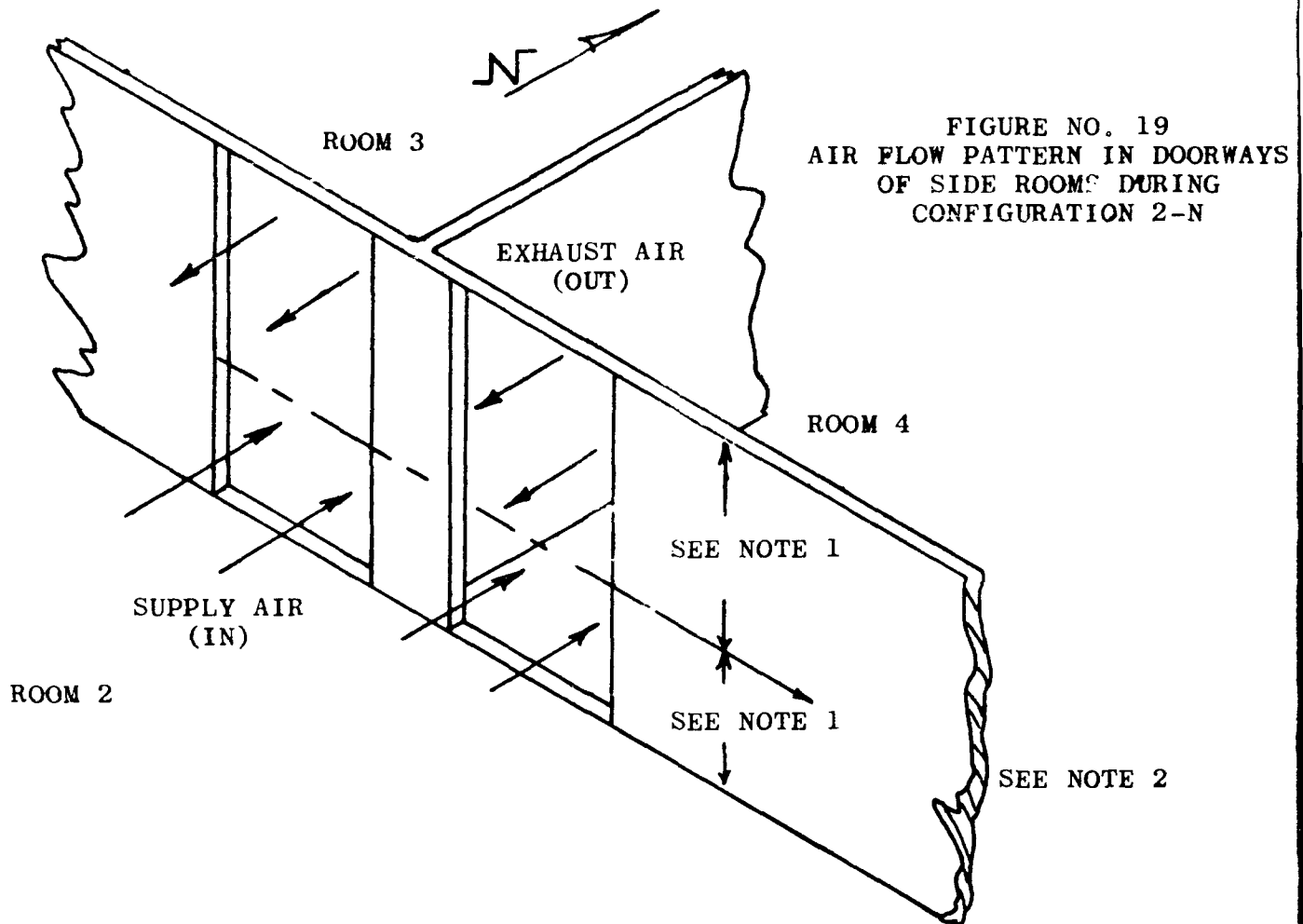
Figure No. 19 which follows, illustrates the air flow pattern at the doorways of Rooms 3 and 4 during tests conducted under Configuration 2-N. The "supply" air enters the side rooms via the bottom section of the doorway; the "exhaust" air exits through the top portion. The areas of the doorway ascribed to "supply" and "exhaust" air depend largely on the thermal currents developed within the side rooms, the relative thermal condition of the two air masses (specific weight) and air currents which might be present at or near the doorways. The latter of these factors was not significant except during Tests 47 and 48, during which time the shelter supply air was baffled toward the doorways of the side rooms (See section of this report entitled "Air Flow Patterns" for the response of the side rooms during such tests.)

The volume of air which passes through these doorways (i.e., the ventilation rate of the side rooms) depends on the aforementioned factors; also the flow rate is limited by the size of the doorway. Air flow rates into the side rooms were determined by a heat balance method which utilized the difference between the heat content of the "supply" and "exhaust" air. A sample calculation using this method of air flow determination is included in this report as Appendix A-3. The thermal conditions of "inlet" and "exhaust" air were determined by a 12 point traverse at the doorway. (The area associated with each flow direction had previously been determined by the generation of smoke patterns within the doorway.)

The lower portion of Figure 19 shows the areas in the center of which measurements were made during Test 30; the temperatures for the areas shown are listed. The height of the boundary line separating inlet and exhaust areas of the doorway did not vary appreciably from test to test and was in general located approximately 43 inches above the floor.

Table VI is a summary of 17 ventilation rates which were determined by the heat balance method. Comparing the ventilation rates of Rooms 3 and 4 for any test, it can be seen that these rates differ only slightly, lending support to the supposition that the flow generated by the thermal output of the simocs is not a linear function of the number of simocs, but is controlled by the door geometry.

A maximum ventilation rate of 375 cfm was recorded during Test 39 for both Rooms 3 and 4. This rate corresponds the per capita rates of 19.7 and 28.8 cubic feet per minute, respectively. The effective temperatures of Rooms 3 and 4 during this same period were 85.5 F and 83.5 F, respectively.



TYPICAL TRAVERSE AREA LAYOUT  
(Actual values given in Table at Left)

	1	2	3					
	4	5	6					
43"	7	8	9					
	10	11	12					See Note 1

FRONT VIEW OF DOORWAYS LEADING TO ROOMS 3 & 4

VALUES FOR TEMPERATURES  
WITHIN TRAVERSED AREA

(Test 30, Room 3)

	db	db	wb
Exhaust	1	96.3	87.3
	2	96.8	86.7
	3	96.3	87.2
	4	95.7	87.8
	5	96.0	87.5
	6	96.3	87.5
Supply	7	94.0	81.3
	8	94.0	81.7
	9	93.8	81.3
	10	93.8	80.9
	11	94.0	81.5
	12	94.0	80.7

NOTES:

- 1) The height at which the boundary was established between Inlet and Exhaust air was determined by the generation of "smoke" patterns within the doorway for each temperature traverse.
- 2) Boundary lines were well defined within a range of 3 to 6 inches for all tests conducted.

TABLE VI  
Summary of Ventilation Rates as Determined by Heat Balance Method

Test No.	Config. No.	Average Inlet Temp. ***		Average Exhaust Temp. ***		Ventilation Rate (CFM)	
		Room 3	Room 4	Room 3	Room 4	Room 3	Room 4
		db, wb	db, wb	db, wb	db, wb		
24*	2-N	88.3, 78.9	88.0, 78.6	92.1, 84.2	90.2, 82.5	302	289
24**	2-N	94.7, 82.3	94.5, 81.4	96.1, 86.9	94.5, 85.2	329	278
26	2-N	Not Taken	81.0, 76.0	Not Taken	85.9, 79.9	Not Taken	300
30	2-N	94.0, 81.4	94.2, 80.9	96.4, 87.5	95.6, 85.5	251	224
31	2-N	93.3, 80.9	93.5, 80.9	95.1, 86.8	95.0, 84.9	251	266
34	2-N	87.7, 79.0	87.5, 78.7	91.9, 84.2	90.9, 82.3	307	317
39	2-N	83.6, 78.6	83.5, 78.2	88.6, 83.0	88.2, 81.3	375	374
40	2-N	89.0, 79.9	88.7, 79.5	92.6, 85.6	91.7, 83.2	275	304
44	2-N	93.6, 81.5	93.9, 81.5	94.6, 86.8	94.8, 84.8	288	325

\* Inlet and Exhaust entry temperatures correspond to shelter response at 0100.

\*\* Inlet and Exhaust entry temperatures correspond to shelter response at 1400.

\*\*\* The Inlet and Exhaust conditions of the air were determined by a twelve point traverse using a battery operated aspirating psychrometer.

Tracer Gas Measurements were made during a number of tests to estimate air exchange rates. As described in the Section, "Operational Procedures", a shelter room to be tested was "dosed" with carbon dioxide, then depletion of the tracer gas with time was determined and by a mathematical operation, made to indicate the number of air changes per minute. A correction was made to allow for the fact that some of the tracer gas was recirculating to the area under test. The results of a number of such tests are shown in Table VII. When average values for the air flow through the doorways are determined, it is found that for Room 3, the average of all tests made under the 2-N (no Punkahs) Configuration, is 307 cfm, while for Room 4 under this same Configuration, the average ventilation is 333 cfm. The individual corrected ventilation rates do not differ significantly from these averages, indicating that the ventilation rates through the doorways are independent of shelter ventilation rates and supply air temperatures. The same is generally true for the configurations where Punkahs were employed, here the ventilation rates are 1300 cfm for Room 3 and 1100 for Room 4, and while individual test results differ from these values by up to 50%, there does not seem to be any regular dependence on shelter ventilation rate or supply air temperatures. Considering the uncertainty in the correction factors when Punkahs were employed, the variations are not significant.

As noted in the discussion accompanying the section on ventilation rates determined by heat balances, it appears that ventilation through a doorway is largely independent of the conditions existing outside the doorway. Since the air supply for the side rooms comes from and returns to the same area (Room 2), the side rooms act simply as heaters and saturators, and raise the air through the same range of temperature and humidity regardless of the initial conditions. The ventilation rate becomes a function of the thermal ("stack") effect of the rise in temperature and humidity and the doorway dimensions.

TABLE VII Summary of Ventilation Rates Determined by Gas Tracer Method

Test No.	Room No.	Shelter Ventilation Rate (Cfm/occ)	Config. No.	Apparent Ventilation Rate (Cfm)	Correction Value 1-(C Inlet/C exhaust)	Corrected Ventilation Rate (Cfm)**
17	4	13.5	1-P	166	0.32	518
17	3	13.5	1-P	262	0.32	820
20	4	22.5	1-P	273	0.55	495
22	4	10.5	1-P	202	0.26	775
24***	3	13.5	1-P	133	0.32	418
26	4	13.5	2-N	260	0.75	347
27	3	13.5	2-P	417	0.32	1300
27	4	13.5	2-P	382	0.32	1190
30	3	13.5	2-N	195	0.75	260
30	4	13.5	2-N	220	0.75	293
31	3	18.2	2-N	184	0.80	230
32	4	18.2	2-P	370	0.44	842
32	3	18.2	2-P	466	0.44	1060
33	3	18.2	2-P	551	0.44	1190
34	4	18.2	2-N	295	0.80	369
34	3	18.2	2-N	292	0.80	365
37	4	18.2	2-P	375	0.44	852
38	3	10.5	2-P	367	0.26	1400
38	4	10.5	2-P	380	0.26	1460
39	4	10.5	2-P	300	0.26	1150
40	4	10.5	2-N	225	0.72	313
40	3	10.5	2-N	169	0.72	235
41	3	10.5	2-P	374	0.26	1440
41	4	10.5	2-P	335	0.26	1290
42	4	8.0	2-P	310	0.20	1550
42	3	8.0	2-P	339	0.20	1685
43	4	8.0	2-N	274	0.70	391
43	3	8.0	2-N	345	0.70	493
44	3	21.0	2-N	208	0.81	257
44	4	21.0	2-N	231	0.81	285
50	4	13.5	2-P	240	0.32	750
52-R	4	22.5	2-P	413	0.55	750
52-R	3	22.5	2-P	546	0.55	994
51-	3	22.5	2-N	366	0.81	452
53***	3	25.0	1-N	187	0.84	223

\* Ventilation rate based on assumption that air enters side rooms once, exits, and never returns.

\*\* Ventilation rate considering that some air enters side rooms, exits, and returns again.

\*\*\* CO<sub>2</sub> Test was conducted during maximum response of shelter.

The Package Ventilating Kit (PVK) was tested only to the extent that operating points were chosen from the performance curve and by utilizing a D.C. motor, the fan was driven at the speed necessary to provide the required air flow at that point. Occasional checks were made on speed and static pressure at the fan, but this data was not used to determine fan performance.

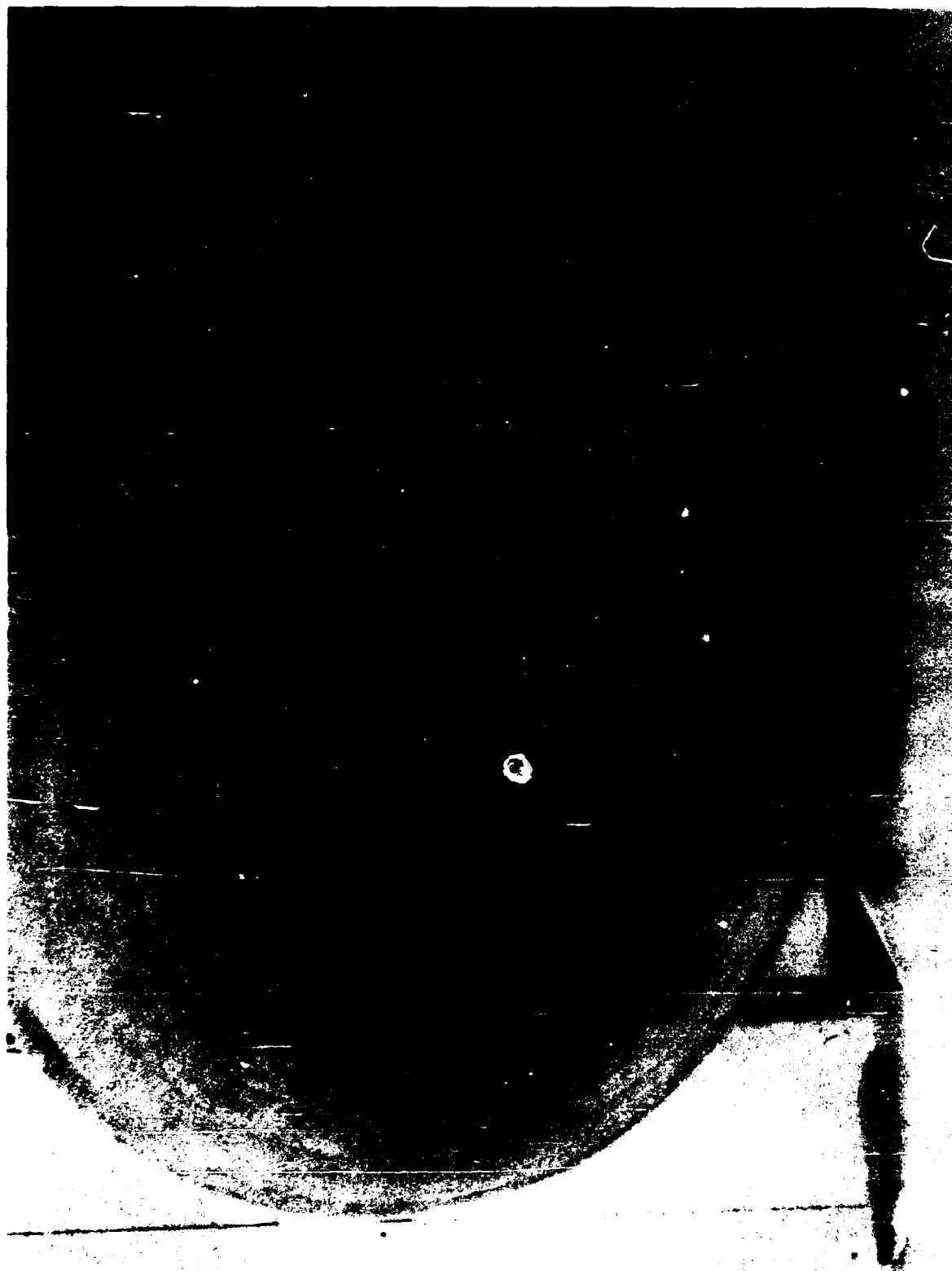
When using the PVK as an exhaust fan, some difficulty was experienced with the application of the polyethylene duct. The duct may not readily be used when it is required to make a sharp turn of more than about 20 degrees. Such a turn causes a crease or partial collapse of the duct resulting in an increase of static pressure within the duct and a significant reduction in the flow rate. Some peripheral support must be provided along the duct at the point of the bend to prevent this collapse.

When the duct was used with its exhaust end unattached severe whipping and snapping was experienced which resulted in splitting of the plastic. In addition, a spontaneous constriction developed three to four duct diameters upstream from the end. Since the constriction did not present a good venturi shape to the flowing air, permanent pressure drop occurred at this point. Both the whipping and the constriction could be prevented by restraining the duct with a heavy object placed inside the end. It was necessary to obstruct about one-third of the area at the duct end to prevent the constriction from developing upstream.

In one portion of the test, the plastic duct was attached to sheet metal ductwork for its passage through the shelter walls. This effectively eliminated any whipping of the duct end, but did not prevent the constriction from developing. Photograph 12 shows the exterior of the duct, while Photograph 13 was taken looking into the metal duct. The asymmetry of the constriction is apparent in this latter view.



Photograph No. 12. Partial Collapse of Exhaust Duct at Juncture  
With Metal Ductwork



Photograph No. 13. View Into Exhaust Duct Showing Constriction

## VII. CONCLUSIONS

A series of thermal response tests were made of a compartmented, adiabatic, simulated protective shelter located in the basement room of the 1000 Persons Protective Shelter at the Protective Structures Development Center, Fort Belvoir, Virginia. The shelter was ventilated at varying rates with air which was conditioned to reproduce the ambient-air conditions expected during a "1% High Design Day", for the rural vicinity of Washington, D.C. (Springfield, Virginia). The thermal response of areas of the shelter was determined when ventilated for extended periods with air which followed a diurnal variation of temperature and humidity. Responses were also determined in a series of steady-state tests in which air at the maximum, average, and minimum conditions occurring during a diurnal cycle was continuously furnished until the shelter environment reached thermal equilibrium. Ventilation of the shelter was accomplished by use of a Package Ventilation Kit utilized in both "supply" and "exhaust" modes and either drawing from, or causing the shelter to draw from a zero pressure plenum which was supplied with the conditioned air. Based on the data taken during the tests, and on observations made by the test personnel, the following conclusions are drawn.

1. The Package Ventilation Kit, because of its flexibility of location, is well suited for ventilation of protective shelters. Ventilation rates of up to 2800 cubic feet per minute were obtainable from the fan of a single PVK, when driven by an electric motor, and with forty-five feet of 20 inch diameter polyethylene duct attached. Evaluation of the fan performance was not within the scope of the contract.
2. A theoretical calculation, supported by actual tests, indicates that the optimum ventilation configuration is one in which air flows in series through shelter rooms or areas. Configurations which permit recirculation of air result in higher average effective temperatures. Proper placement of the shelter ventilating fan, coupled with some capability on the part of the shelter occupants to close some existing openings and create others, can effect a series ventilating path in a compartmented shelter.
3. In the ventilation of a compartmented shelter, flow of air to a "side" room (i.e., a room not in a series air flow path, but connecting to such a "main" room by one or more openings) is largely dependent on thermal currents generated within the room and is little affected by the amount or condition of the air supplied to the "main" room. At the lower ventilation rates, some dependence of the "side" room ventilation on shelter ventilation rates can be shown, due to the sweeping away of the exhaust from the "side" rooms, but in this ventilation rate range, the "side" rooms are uninhabitable from either criterion of effective temperature considered.
4. Employment of Punkah Pumps in doorways exerted a beneficial effect on conditions within otherwise unuseable "side" rooms, with undue adverse effects on the "main" rooms from which they were moving air.
5. An air directing baffle, utilized to cause direct impingement of air on the doorways of "side" rooms, was not a successful approach to improving their ventilation. The directed air stream from a ceiling to floor baffle completely blanketed the doorway and impeded the exit of exhaust air.

6. The flexible polyethylene film tubing furnished to be used as an exhaust duct with the PVK exhibited instability at high air flow rates which could have destroyed it in time. Stable flow could only be obtained by restraining the exit end of the duct and by simultaneously restricting the area of the exit end by about thirty percent. Sharp bends of more than twenty degrees caused a collapse of the sides of the duct which greatly increased its resistance to air flow. A constriction spontaneously developed near the exhaust end of the duct at high air flows which also reduced air handling capability. It is concluded this type of ducting needs further development.

7. Utilization of the PVK in an exhaust configuration was slightly superior, as measured by the conditions noted in the "side" rooms, compared to its employment as a supply fan. A ten percent reduction in the ventilation air supply rate could be made for the exhaust configuration, as compared to the supply configuration, while maintaining the shelter at an average effective temperature of 85.0 F. The effect is believed due to more positive air flow patterns existing in the supply configuration which impeded thermal currents from exiting the "side" room doorways as had been found when an air directing baffle was used.

8. Adiabatic operation of a simulated shelter is realizable in practice by proper insulation of test structures and by maintaining temperature control of the surroundings. When so operated, simulated shelters represent typical areas in the interior cores of multi-story buildings. Deviations of the simulated shelter behavior from that of a "real" shelter result from the fact that tests made of actual shelter areas have not been made under extreme "high design" weather conditions, and therefore have demonstrated heat losses by conduction and radiation that would not be present under the worst conditions, when adiabatic operation will be closely approached. In addition the mass of material (walls, partitions, floor, furnishings, etc.) to be found in a "real" shelter, may be expected to attenuate the amplitude of cyclic temperature variations to a greater degree than that experienced in the simulated shelter which was very lightly constructed.

9. When operated as an "adiabatic" shelter, the response of the structure approached the predicted values very closely. Average shelter effective temperatures did not differ by more than 0.5 degrees from those calculated in advance, and were usually within 0.2 degrees. Effective temperature of any room serving as an exhaust chamber could be predicted with similar accuracy, but temperatures to be expected in "side" rooms could not be predicted with confidence.

10. When subjected to a steady-state test with ventilation air at the average temperature selected from the diurnal cycle, the response of the shelter as a whole very closely approximated the time-averaged response of the shelter, ventilated at the same rate, with air whose conditions followed a diurnal cycle of temperature and humidity variation. The possibility of substituting several 8-10 hour steady-state tests for a 72 hour diurnal test exists, with savings in time and expense.

11. With respect to the actual thermal responses determined, it is concluded that no diurnal ventilation rate tested was adequate to control

all shelter rooms so that a maximum effective temperature was never exceeded; ventilation rates from 10 to 25 cubic feet per minute per occupant were employed. All diurnal ventilation tests conducted at 22-25 cfm per occupant demonstrated the habitability of the room through which the ventilation air first entered the shelter for a criterion of 85 F maximum effective temperature. No diurnal ventilation test conducted at 13.5 cfm per occupant, the room serving as the inlet for ventilation air, was habitable for a criterion of 85 F average effective temperature. Under these conditions, and for this criterion "side" rooms also became habitable when Punkahs were employed.

12. Estimation of ventilation rates for "side" rooms by heat balance measurements and by tracer-gas techniques indicates that ventilation rates of 300-350 cubic feet per minute may be expected for a doorway 32-1/2 by 78-1/2 inches in size. Velocity measurements indicate that the "inlet" portion of this door extends upward 43 inches from the floor, there is a region of about 6 inches in which flow is indeterminate, the balance of the door serves as an exhaust. It is concluded that natural ventilation through doorways is largely independent of conditions existing in a "main" room, except as directed air flows may impede thermal currents.

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APPENDICES

## APPENDIX A-1

Sample Calculations for the Determination of Overall Heat Transmission Coefficient, "U".

### Experimentally Determined "U".

Equation No. 1

$$U = \frac{Q}{A \times \Delta T}$$

Where:

U = Overall Heat Transmission Coefficient (Btu/hr.sq.ft.F)

Q\* = Sensible Heat Liberated within Structure (Btu/hr)

A = Area of Walls and Ceiling (Sq.ft.)

$\Delta T^{**}$  = Temperature gradient @ Steady State (Deg. F)

$$U = \frac{23,500}{2160 \times 8.8} = 1.23 \text{ Btu/hr.sq.ft.F}$$

### Design "U" Determination

Determination of "U" value after addition of Styrofoam Insulation (1 inch thick) to walls and ceiling.

<u>Ceiling Section</u>	
<u>Construction</u>	<u>Resistance (R****)</u>
1. Outside Surface (Still air)****	0.68
2. Styrofoam (1 inch thick)	3.85
3. Vinyl (10 mil)	_____
4. Inside Surface (Still air)	<u>0.68</u>
Total R <sub>1</sub> =	5.21
$U_1 = 1/R_1 = 1/5.21 = 0.192$	

---

\* Heat to structure was electrical energy and was metered by KWH meter - rate was 6.9 KW or 23,500 Btu/hr.

\*\* Average temperature gradient was determined from twelve thermocouple pairs located across walls and ceiling sections.

\*\*\* Resistance values from ASHRAE Guide and Data Book, Chapter 23.

\*\*\*\* Outside surfaces on the exterior of the shelter, were in "still" air, since located within the basement area of Building 2591, F3DC.

<u>Construction</u>	<u>Wall Section (Type A)</u>	<u>Resistance (R)</u>
1. Outside Surface (Still air)		0.68
2. Styrofoam (1 inch thick)		3.85
3. Air Space (3-5/8 inches)		0.91
4. Plywood (1/4 inch thick)		0.31
5. Inside Surface (Still air)		<u>0.68</u>
Total $R_2 =$		6.43

$$U_2 = 1/R = 1/6.43 = 0.155$$

<u>Construction</u>	<u>Wall Section (Type B)</u>	<u>Resistance (R)</u>
1. Outside Surface (Still air)		0.68
2. Styrofoam (1 inch thick)		3.85
3. Plywood (1/4 inch thick)		0.31
4. Inside Surface (Still air)		<u>0.68</u>
Total R =		5.52

$$U_3 = 1/R = 1/5.52 = 0.181$$

Composite Shelter "U" Value (i.e., U value based on a weighted average considering areas of individual sections)

$$U_c = U_1 \times \text{Area ratio} + U_2 \times \text{Area ratio} + U_3 \times \text{Area ratio}$$

$$U_c = 0.192 \times 0.518 + 0.181 \times 0.241 + 0.155 \times 0.241$$

$$U_c = \underline{\underline{0.171 \text{ Btu/hr.sq.ft.F}}}$$

## APPENDIX A-2

Sample Calculations for Prediction of Shelter Effective Temperatures for "Adiabatic" Conditions.

Definition of Symbols used in Calculations:

$$h = \text{Enthalpy of moist air} - \frac{\text{Btu}}{\text{lb.dry air}}$$

$$v = \text{Specific volume of moist air} - \text{ft}^3/\text{lb.dry air}$$

$$w = \text{Moisture content of air} - \frac{\text{lb. moisture}}{\text{lb.dry air}}$$

$$T_{db} = \text{Dry bulb temperature of air}$$

$$T_{wb} = \text{Wet bulb temperature of air}$$

$$\dot{m} = \text{Mass flow rate of air supplied to shelter} - \frac{\text{lb.air}}{\text{min.occ}}$$

$$Q = \text{Volume flow rate of air supplied to shelter} - \frac{\text{ft}^3}{\text{min.occ}}$$

Problem: Determine the effective temperature resulting from an assumed ventilation rate of  $13.5 \text{ ft}^3/\text{min.occ}$ .

Solution:

Given:

Ventilation air supplied at  $T_{db} = 84.6 \text{ F}$  and

$T_{wb} = 75.5 \text{ F}$  corresponding to average design day conditions

Let: Subscript 1 denote supply condition

Subscript 2 denote exhaust condition

From Psychrometric Chart at condition 1:

$$h_1 = 39.07 \text{ Btu/lb.dry air}$$

$$v_1 = 14.17 \text{ ft}^3/\text{lb.dry air}$$

$$w_1 = 0.017 \text{ lb.moisture/lb.dry air}$$

$$\dot{m} = \frac{Q}{v_1} = \frac{13.5}{14.17} = 0.952 \frac{\text{lb.air}}{\text{min. occ}}$$

$\Delta h_{2-1}$  = heat release in shelter is 400 Btu/hr.occ or

$$\frac{400}{(60)(0.952)} = 7.00 \text{ Btu/lb.dry air}$$

$$h_2 = h_1 + \Delta h_{2-1} = 39.07 + 7.00 = \underline{46.07 \text{ Btu/lb.dry air}}$$

Assume  $T_{db_2} = 90 \text{ F}$  Latent Heat Loss @ 90 F =  $0.274 \frac{\text{lb.water}}{\text{hr.occ.}}$

$$w_2 = \frac{\frac{0.274}{60} + (0.952)(0.017)}{0.952} = 0.0218 \frac{\text{lb.moisture}}{\text{lb.dry air}}$$

From Psychrometric Chart @ 90 F and  $0.0218 \frac{\text{lb.moisture}}{\text{lb.dry air}}$

$$h_2 = \underline{45.70 \text{ Btu/lb.dry air}}$$

Therefore the assumption of  $T_{db_2} = 90 \text{ F}$  was too low

Assume  $T_{db_2} = 91 \text{ F}$  Latent Heat Loss @ 91 F =  $0.2830 \frac{\text{lb.water}}{\text{hr.occ.}}$

$$w_2 = \frac{\frac{0.2830}{60} + 0.0162}{0.952} = 0.02195 \frac{\text{lb.moisture}}{\text{lb.dry air}}$$

$$h_2 = \underline{46.06 \text{ Btu/lb.dry air}}$$

This agrees closely with the required  $h_2$  of 46.07 Btu/lb.dry air

From Psychrometric Chart @ 91 F and  $0.02195 \frac{\text{lb.moisture}}{\text{lb.dry air}}$

$$T_{db_2} = 91.0 \text{ F}$$

$$T_{wb_2} = 82.2 \text{ F}$$

This gives a predicated effective temperature of 85.2 F.

From Psychrometric Chart at conditions 2:

$$h_2 = 46.35 \text{ Btu/lb.dry air}$$

$$v_2 = 14.35 \text{ ft}^3/\text{lb.dry air}$$

Equation 1:

$$Q_{xM} = M(h_2 - h_1) \times 60$$

Therefore:

$$M = \frac{Q \times n}{(h_2 - h_1) \times 60} = \frac{400 \times 13}{(46.35 - 42.30) \times 60}$$

$$M = 21.2 \frac{\text{lb.dry air}}{\text{min}}$$

Equation 2:

$$V = M \bar{v}$$

Where:  $\bar{v}$  = Average specific volume  
of conditions 1 and 2

$$V = 21.2 \times 14.27$$

$$V = \underline{303 \text{ ft}^3/\text{min.}}$$

---

\*

It is assumed that the side rooms are adiabatic and that all of the heat generated by the Simocs (400 Btu/hr.occ) is carried out in the ventilation air stream.

\*\*

The inlet and exhaust conditions of air were previously determined by a twelve point traverse using a battery operated aspirating psychrometer. The areas assigned to inlet and exhaust air stream were determined by a "smoke" pattern traverse taken prior to temperature traverse.

### APPENDIX A-3

#### Sample Calculations of Air Flow Rate Determination Using Heat Balance Method.

##### Definition of Symbols used in Calculations:

$h$  = Enthalpy of moist air -  $\frac{\text{Btu}}{\text{lb.dry air}}$

$v$  = Specific volume of moist air -  $\text{ft}^3/\text{lb.dry air}$

$T_{db}$  = Dry bulb temperature of air

$T_{wb}$  = Wet bulb temperature of air

$M$  = Mass flow rate of air -  $\frac{\text{lb.air}}{\text{min.}}$

$n$  = Number of occupants simulated (Room 4)

$Q^*$  = Metabolic heat released by Simoc -  $\text{Btu/hr.occ}$

$V$  = Flow rate of air -  $\text{ft}^3/\text{min}$

Given: \*\*

- 1) Inlet air conditions in lower portion of doorway @  
 $T_{db} = 87.2 \text{ F}$  and  $T_{wb} = 78.7 \text{ F}$ .
- 2) Exhaust air conditions in upper portion of doorway @  
 $T_{db} = 90.2 \text{ F}$  and  $T_{wb} = 82.3 \text{ F}$ .

Let:

Subscript 1 denote inlet conditions.

Subscript 2 denote exhaust conditions.

From Psychrometric Chart at condition 1:

$$h_1 = 42.30 \text{ Btu/lb.dry air}$$

$$v_1 = 14.2 \text{ ft}^3/\text{lb.dry air}$$

From Psychrometric Chart at conditions 2:

$$h_2 = 46.35 \text{ Btu/lb.dry air}$$

$$v_2 = 14.35 \text{ ft}^3/\text{lb.dry air}$$

Equation 1:

$$Q = M(h_2 - h_1)$$

Therefore:

$$M = \frac{Q \times n}{(h_2 - h_1)} = \frac{400 \times 13}{4.35 - 42.30}$$

$$M = 1273 \frac{\text{lb.dry air}}{\text{hr}} \quad \text{or} \quad 21.2 \frac{\text{lb.dry air}}{\text{min}}$$

Equation 2:

$$V = M \bar{v}$$

Where:  $\bar{v}$  = Average specific volume  
of conditions 1 and 2

$$V = 21.2 \times 14.57$$

$$V = \underline{312 \text{ ft}^3/\text{min}}$$

---

\* It is assumed that the side rooms are adiabatic and that all of the heat generated by the Simocs (400 Btu/hr.occ) is carried out in the ventilation air stream.

\*\* The inlet and exhaust conditions of air were previously determined by a twelve point traverse using a battery operated aspirating psychrometer. The areas assigned to inlet and exhaust air streams were determined by a "smoke" pattern traverse taken prior to temperature traverse.

APPENDIX B  
TEMPERATURE DATA TABULATION

TABLE I-B

## Index to Temperature Data

The data contained in Table I-B is listed in chronological order. In order that this data can be made readily accessible, the following index relates the test number, with the period during which the test was conducted. The significance of data points 1-49 in Table II-B may be determined by reference to Tables III and IV in the body of the report.

<u>TEST NO.</u>	<u>TEST PERIOD</u> <u>(Date &amp; Time)</u>				
1	1200	4/20/65	through	1600	4/24/65
2	0600	4/27/65	through	1800	4/27/65
3	1900	4/27/65	through	0200	4/28/65
4	0300	4/28/65	through	1700	4/28/65
5	1800	4/28/65	through	2300	4/28/65
6	2400	4/28/65	through	1100	4/29/65
7	1200	4/29/65	through	1700	4/29/65
8	1800	4/29/65	through	2300	4/29/65
9	2400	4/29/65	through	1000	4/30/65
10	1100	4/30/65	through	1700	4/30/65
11	2200	4/30/65	through	0800	5/1/65
12	0300	5/3/65	through	1400	5/3/65
13	1500	5/3/65	through	0300	5/4/65
14	0400	5/4/65	through	1400	5/4/65
15	1500	5/4/65	through	2200	5/4/65
16	2300	5/4/65	through	0500	5/5/65
17	0600	5/5/65	through	1500	5/5/65
18	1600	5/5/65	through	2200	5/5/65
19	2300	5/5/65	through	0700	5/6/65
20	0800	5/6/65	through	1700	5/6/65
21	1800	5/6/65	through	0100	5/7/65
22	0200	5/7/65	through	1200	5/7/65

TABLE I-B, CONTINUED

<u>TEST NO.</u>	<u>TEST PERIOD</u> <u>(Date &amp; Time)</u>				
23	1800	5/7/65	through	0100	5/8/65
24	1700	5/9/65	through	1700	5/13/65
25	1800	5/13/65	through	2400	5/13/65
26	0100	5/14/65	through	1600	5/14/65
27	0400	5/17/65	through	1100	5/14/65
28	1200	5/17/65	through	2000	5/17/65
29	2100	5/17/65	through	0200	5/18/65
30	0300	5/18/65	through	0900	5/18/65
31	1200	5/18/65	through	2000	5/18/65
32	2100	5/18/65	through	2400	5/18/65
33	0100	5/19/65	through	0500	5/19/65
34	0600	5/19/65	through	1300	5/19/65
35	1400	5/19/65	through	2300	5/19/65
36	2400	5/19/65	through	1200	5/20/65
37	1300	5/20/65	through	1900	5/20/65
38	2100	5/20/65	through	1000	5/21/65
39	1100	5/21/65	through	1500	5/21/65
40	1600	5/21/65	through	2400	5/21/65
41	1000	5/23/65	through	2000	5/23/65
42	2100	5/23/65	through	0900	5/24/65
43	1000	5/24/65	through	2000	5/24/65
44	2100	5/24/65	through	1600	5/25/65
45	1700	5/25/65	through	1100	5/26/65
46	2300	5/26/65	through	1800	5/29/65
47	1900	5/29/65	through	1800	6/1/65
48	1900	6/1/65	through	1900	6/4/65

TABLE I-B, CONTINUED

TEST NO.	TEST PERIOD				
	(Date & Time)				
49	2000	6/4/65	through	1800	6/6/65
50	1900	6/6/65	through	1800	6/8/65
51	2000	6/8/65	through	0300	6/9/65
52	0400	6/9/65	through	1200	6/9/65
51-R*	1300	6/9/65	through	1700	6/9/65
42-R*	2100	6/9/65	through	0300	6/10/65
43-R*	0400	6/10/65	through	1200	6/10/65
43-RR**	1800	6/10/65	through	0700	6/11/65
42-RR**	0800	6/11/65	through	1900	6/11/65
53	0100	6/12/65	through	1800	6/14/65
54	1900	6/14/65	through	0300	6/15/65
55	1700	6/15/65	through	1800	6/17/65
56	2100	6/17/65	through	0700	6/18/65
57	0900	6/18/65	through	1600	6/18/65
58	1700	6/18/65	through	2400	6/18/65
59	0100	6/19/65	through	1000	6/19/65
60	1100	6/19/65	through	1800	6/19/65
61	2200	6/19/65	through	0900	6/20/65
62	1000	6/20/65	through	1900	6/20/65
63	2000	6/20/65	through	1500	6/21/65
64	1600	6/21/65	through	2200	6/21/65
65	2300	6/21/65	through	1800	6/24/65
38-R*	2200	6/24/65	through	1000	6/25/65
52-R	1100	6/25/65	through	1800	6/25/65

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\* Repeat of Numbered Test

\*\* Second Repeat of Numbered Test



TIME	WAVE	DATE	4/2/1965	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP
1	1000	4	1000	4	1000	4	1000	4
2	1000	4	1000	4	1000	4	1000	4
3	1000	4	1000	4	1000	4	1000	4
4	1000	4	1000	4	1000	4	1000	4
5	1000	4	1000	4	1000	4	1000	4
6	1000	4	1000	4	1000	4	1000	4
7	1000	4	1000	4	1000	4	1000	4
8	1000	4	1000	4	1000	4	1000	4
9	1000	4	1000	4	1000	4	1000	4
10	1000	4	1000	4	1000	4	1000	4
11	1000	4	1000	4	1000	4	1000	4
12	1000	4	1000	4	1000	4	1000	4
13	1000	4	1000	4	1000	4	1000	4
14	1000	4	1000	4	1000	4	1000	4
15	1000	4	1000	4	1000	4	1000	4
16	1000	4	1000	4	1000	4	1000	4
17	1000	4	1000	4	1000	4	1000	4
18	1000	4	1000	4	1000	4	1000	4
19	1000	4	1000	4	1000	4	1000	4
20	1000	4	1000	4	1000	4	1000	4
21	1000	4	1000	4	1000	4	1000	4
22	1000	4	1000	4	1000	4	1000	4
23	1000	4	1000	4	1000	4	1000	4
24	1000	4	1000	4	1000	4	1000	4
25	1000	4	1000	4	1000	4	1000	4
26	1000	4	1000	4	1000	4	1000	4
27	1000	4	1000	4	1000	4	1000	4
28	1000	4	1000	4	1000	4	1000	4
29	1000	4	1000	4	1000	4	1000	4
30	1000	4	1000	4	1000	4	1000	4
31	1000	4	1000	4	1000	4	1000	4
32	1000	4	1000	4	1000	4	1000	4
33	1000	4	1000	4	1000	4	1000	4
34	1000	4	1000	4	1000	4	1000	4
35	1000	4	1000	4	1000	4	1000	4
36	1000	4	1000	4	1000	4	1000	4
37	1000	4	1000	4	1000	4	1000	4
38	1000	4	1000	4	1000	4	1000	4
39	1000	4	1000	4	1000	4	1000	4
40	1000	4	1000	4	1000	4	1000	4
41	1000	4	1000	4	1000	4	1000	4
42	1000	4	1000	4	1000	4	1000	4
43	1000	4	1000	4	1000	4	1000	4
44	1000	4	1000	4	1000	4	1000	4
45	1000	4	1000	4	1000	4	1000	4
46	1000	4	1000	4	1000	4	1000	4
47	1000	4	1000	4	1000	4	1000	4
48	1000	4	1000	4	1000	4	1000	4
49	1000	4	1000	4	1000	4	1000	4
50	1000	4	1000	4	1000	4	1000	4

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TIME 1500		DATE 4/22/1965									
TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
1	74.5	7	74.1	13	82.0	19	84.5	25	85.0	31	78.5
8	81.0	14	84.0	20	83.0	26	84.5	32	84.5	38	84.5
15	74.0	21	84.2	27	85.0	33	89.0	39	87.5	45	100.0
22	76.2	28	84.0	34	84.5	40	83.5	46	78.0	52	84.5
29	70.5	35	83.5	41	85.0	47	95.0	53	95.5	59	95.5
36	75.5	42	84.0	48	85.5	54	84.5	60	84.5	66	94.5
43	74.5	49	87.0	55	93.0	61	84.0	67	70.5	73	84.0

TIME 1600		DATE 4/22/1965									
TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
1	74.0	7	74.0	13	84.0	19	84.0	25	85.0	31	85.0
8	82.0	14	87.0	20	83.5	26	87.0	32	86.0	38	93.0
15	74.0	21	82.0	27	87.5	33	89.0	39	88.0	45	101.0
22	87.0	28	84.0	34	84.0	40	83.0	46	78.0	52	88.0
29	74.0	35	92.0	41	95.5	47	95.0	53	95.5	59	95.0
36	75.5	42	87.0	48	98.0	54	88.5	60	84.5	66	94.5
43	75.0	49	89.5	55	92.0	61	84.0	67	70.0	73	89.0

27	08.1	23	28	33	38	43	48	53	58	63	68	73	78	83	88	93
27	17.5	1	10.0	31	65.5	52	91.0	33	74.5	36	64.0	34	61.0	32	59.5	31
30	92.0	37	61.0	33	81.0	39	51.5	41	86.0	51	67.0	42	80.5	48	60.5	35
33	98.0	44	51.0	43	85.5	46	65.5	47	72.5	48	70.0	49	67.0	50	64.0	47

TIME	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200
PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT
1	10.0	1	10.0	1	91.0	1	11.0	1	11.0	1	88.5	1	92.0	1	89.0	1
15	10.0	16	90.0	17	91.0	18	89.5	19	90.5	20	92.0	21	90.5	22	91.5	23
30	10.0	31	90.0	32	91.0	33	89.5	34	90.5	35	92.0	36	90.5	37	91.5	38
45	10.0	46	90.0	47	91.0	48	89.5	49	90.5	50	92.0	51	90.5	52	91.5	53
60	10.0	61	90.0	62	91.0	63	89.5	64	90.5	65	92.0	66	90.5	67	91.5	68
75	10.0	76	90.0	77	91.0	78	89.5	79	90.5	80	92.0	81	90.5	82	91.5	83
90	10.0	91	90.0	92	91.0	93	89.5	94	90.5	95	92.0	96	90.5	97	91.5	98
105	10.0	106	90.0	107	91.0	108	89.5	109	90.5	110	92.0	111	90.5	112	91.5	113
120	10.0	121	90.0	122	91.0	123	89.5	124	90.5	125	92.0	126	90.5	127	91.5	128
135	10.0	136	90.0	137	91.0	138	89.5	139	90.5	140	92.0	141	90.5	142	91.5	143
150	10.0	151	90.0	152	91.0	153	89.5	154	90.5	155	92.0	156	90.5	157	91.5	158
165	10.0	166	90.0	167	91.0	168	89.5	169	90.5	170	92.0	171	90.5	172	91.5	173
180	10.0	181	90.0	182	91.0	183	89.5	184	90.5	185	92.0	186	90.5	187	91.5	188
195	10.0	196	90.0	197	91.0	198	89.5	199	90.5	200	92.0	201	90.5	202	91.5	203
210	10.0	211	90.0	212	91.0	213	89.5	214	90.5	215	92.0	216	90.5	217	91.5	218
225	10.0	226	90.0	227	91.0	228	89.5	229	90.5	230	92.0	231	90.5	232	91.5	233
240	10.0	241	90.0	242	91.0	243	89.5	244	90.5	245	92.0	246	90.5	247	91.5	248
255	10.0	256	90.0	257	91.0	258	89.5	259	90.5	260	92.0	261	90.5	262	91.5	263
270	10.0	271	90.0	272	91.0	273	89.5	274	90.5	275	92.0	276	90.5	277	91.5	278
285	10.0	286	90.0	287	91.0	288	89.5	289	90.5	290	92.0	291	90.5	292	91.5	293
300	10.0	301	90.0	302	91.0	303	89.5	304	90.5	305	92.0	306	90.5	307	91.5	308
315	10.0	316	90.0	317	91.0	318	89.5	319	90.5	320	92.0	321	90.5	322	91.5	323
330	10.															

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TIME		1966		LISTE		4/27/1965		1966		1967		1968		1969		1970	
P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T
0	00.0	1	00.0	1	00.0	1	00.0	1	00.0	1	00.0	1	00.0	1	00.0	1	00.0
1	00.1	2	00.1	2	00.1	2	00.1	2	00.1	2	00.1	2	00.1	2	00.1	2	00.1
2	00.2	3	00.2	3	00.2	3	00.2	3	00.2	3	00.2	3	00.2	3	00.2	3	00.2
3	00.3	4	00.3	4	00.3	4	00.3	4	00.3	4	00.3	4	00.3	4	00.3	4	00.3
4	00.4	5	00.4	5	00.4	5	00.4	5	00.4	5	00.4	5	00.4	5	00.4	5	00.4
5	00.5	6	00.5	6	00.5	6	00.5	6	00.5	6	00.5	6	00.5	6	00.5	6	00.5
6	00.6	7	00.6	7	00.6	7	00.6	7	00.6	7	00.6	7	00.6	7	00.6	7	00.6
7	00.7	8	00.7	8	00.7	8	00.7	8	00.7	8	00.7	8	00.7	8	00.7	8	00.7
8	00.8	9	00.8	9	00.8	9	00.8	9	00.8	9	00.8	9	00.8	9	00.8	9	00.8
9	00.9	10	00.9	10	00.9	10	00.9	10	00.9	10	00.9	10	00.9	10	00.9	10	00.9
10	01.0	11	01.0	11	01.0	11	01.0	11	01.0	11	01.0	11	01.0	11	01.0	11	01.0
11	01.1	12	01.1	12	01.1	12	01.1	12	01.1	12	01.1	12	01.1	12	01.1	12	01.1
12	01.2	13	01.2	13	01.2	13	01.2	13	01.2	13	01.2	13	01.2	13	01.2	13	01.2
13	01.3	14	01.3	14	01.3	14	01.3	14	01.3	14	01.3	14	01.3	14	01.3	14	01.3
14	01.4	15	01.4	15	01.4	15	01.4	15	01.4	15	01.4	15	01.4	15	01.4	15	01.4
15	01.5	16	01.5	16	01.5	16	01.5	16	01.5	16	01.5	16	01.5	16	01.5	16	01.5
16	01.6	17	01.6	17	01.6	17	01.6	17	01.6	17	01.6	17	01.6	17	01.6	17	01.6
17	01.7	18	01.7	18	01.7	18	01.7	18	01.7	18	01.7	18	01.7	18	01.7	18	01.7
18	01.8	19	01.8	19	01.8	19	01.8	19	01.8	19	01.8	19	01.8	19	01.8	19	01.8
19	01.9	20	01.9	20	01.9	20	01.9	20	01.9	20	01.9	20	01.9	20	01.9	20	01.9
20	02.0	21	02.0	21	02.0	21	02.0	21	02.0	21	02.0	21	02.0	21	02.0	21	02.0
21	02.1	22	02.1	22	02.1	22	02.1	22	02.1	22	02.1	22	02.1	22	02.1	22	02.1
22	02.2	23	02.2	23	02.2	23	02.2	23	02.2	23	02.2	23	02.2	23	02.2	23	02.2
23	02.3	24	02.3</														

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524
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TIME		DATE		4/24/1965							
1	TEMP	1	TEMP	1	TEMP	1	TEMP	1	TEMP	1	TEMP
1	93.0	2	94.5	3	93.5	4	94.7	5	92.0	6	91.9
7	91.0	8	94.0	9	85.5	10	93.0	11	92.0	12	92.0
13	93.5	14	94.9	15	94.0	16	87.3	17	94.5	18	95.2
19	94.6	20	94.1	21	94.1	22	92.0	23	94.0	24	93.0
25	94.6	26	94.0	27	94.0	28	92.0	29	94.0	30	94.5
31	94.6	32	94.7	33	95.0	34	95.0	35	94.0	36	94.0
37	93.0	38	94.7	39	95.0	40	95.0	41	94.0	42	94.0
43	93.0	44	94.7	45	95.0	46	95.0	47	94.0	48	94.0
49	93.0	50	94.7	51	95.0	52	95.0	53	94.0	54	94.0

[illegible]

TIME (1000)		4/21/1965							
P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP
1	87.5	1	87.5	1	87.5	1	87.5	1	87.5
2	87.5	2	87.5	2	87.5	2	87.5	2	87.5
3	87.5	3	87.5	3	87.5	3	87.5	3	87.5
4	87.5	4	87.5	4	87.5	4	87.5	4	87.5
5	87.5	5	87.5	5	87.5	5	87.5	5	87.5
6	87.5	6	87.5	6	87.5	6	87.5	6	87.5
7	87.5	7	87.5	7	87.5	7	87.5	7	87.5
8	87.5	8	87.5	8	87.5	8	87.5	8	87.5
9	87.5	9	87.5	9	87.5	9	87.5	9	87.5
10	87.5	10	87.5	10	87.5	10	87.5	10	87.5
11	87.5	11	87.5	11	87.5	11	87.5	11	87.5
12	87.5	12	87.5	12	87.5	12	87.5	12	87.5
13	87.5	13	87.5	13	87.5	13	87.5	13	87.5
14	87.5	14	87.5	14	87.5	14	87.5	14	87.5
15	87.5	15	87.5	15	87.5	15	87.5	15	87.5
16	87.5	16	87.5	16	87.5	16	87.5	16	87.5
17	87.5	17	87.5	17	87.5	17	87.5	17	87.5
18	87.5	18	87.5	18	87.5	18	87.5	18	87.5
19	87.5	19	87.5	19	87.5	19	87.5	19	87.5
20	87.5	20	87.5	20	87.5	20	87.5	20	87.5
21	87.5	21	87.5	21	87.5	21	87.5	21	87.5
22	87.5	22	87.5	22	87.5	22	87.5	22	87.5
23	87.5	23	87.5	23	87.5	23	87.5	23	87.5
24	87.5	24	87.5	24	87.5	24	87.5	24	87.5
25	87.5	25	87.5	25	87.5	25	87.5	25	87.5
26	87.5	26	87.5	26	87.5	26	87.5	26	87.5
27	87.5	27	87.5	27	87.5	27	87.5	27	87.5
28	87.5	28	87.5	28	87.5	28	87.5	28	87.5
29	87.5	29	87.5	29	87.5	29	87.5	29	87.5
30	87.5	30	87.5	30	87.5	30	87.5	30	87.5
31	87.5	31	87.5	31	87.5	31	87.5	31	87.5
32	87.5	32	87.5	32	87.5	32	87.5	32	87.5
33	87.5	33	87.5	33	87.5	33	87.5	33	87.5
34	87.5	34	87.5	34	87.5	34	87.5	34	87.5
35	87.5	35	87.5	35	87.5	35	87.5	35	87.5
36	87.5	36	87.5	36	87.5	36	87.5	36	87.5
37	87.5	37	87.5	37	87.5	37	87.5	37	87.5
38	87.5	38	87.5	38	87.5	38	87.5	38	87.5
39	87.5	39	87.5	39	87.5	39	87.5	39	87.5
40	87.5	40	87.5	40	87.5	40	87.5	40	87.5
41	87.5	41	87.5	41	87.5	41	87.5	41	87.5
42	87.5	42							

PI TEMP		PI TEMP		PI TEMP		PI TEMP		PI TEMP		PI TEMP	
PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP
1 46.5	7 10.5	5 8.5	4 81.0	5 87.0	7 80.0	7 85.5					
2 19.0	7 10.0	11 12.5	11 13.0	12 79.0	13 76.5	14 74.5					
15 18.0	16 11.0	17 88.0	25 85.0	17 87.0	30 82.0	21 86.0					
22 82.0	23 11.0	24 11.0	25 75.0	26 72.0	27 86.0	28 83.0					
29 82.0	30 11.0	31 87.0	32 75.0	33 87.0	34 86.0	35 88.5					
36 67.0	37 11.0	38 82.0	39 78.0	40 82.0	41 82.5	42 84.5					
43 56.5	44 11.0	45 82.0	46 78.0	47 71.0	48 84.0	49 80.5					

[illegible]

TIME		15.00		15.30		16.00		16.30		17.00		17.30		18.00		18.30		19.00		19.30		20.00		20.30		21.00		21.30		22.00		22.30		23.00		23.30		24.00		24.30		25.00		25.30		26.00		26.30		27.00		27.30		28.00		28.30		29.00		29.30		30.00		30.30		31.00		31.30		32.00		32.30		33.00		33.30		34.00		34.30		35.00		35.30		36.00		36.30		37.00		37.30		38.00		38.30		39.00		39.30		40.00		40.30		41.00		41.30		42.00		42.30		43.00		43.30		44.00		44.30		45.00		45.30		46.00		46.30		47.00		47.30		48.00		48.30		49.00		49.30		50.00		50.30		51.00		51.30		52.00		52.30		53.00		53.30		54.00		54.30		55.00		55.30		56.00		56.30		57.00		57.30		58.00		58.30		59.00		59.30		60.00		60.30		61.00		61.30		62.00		62.30		63.00		63.30		64.00		64.30		65.00		65.30		66.00		66.30		67.00		67.30		68.00		68.30		69.00		69.30		70.00		70.30		71.00		71.30		72.00		72.30		73.00		73.30		74.00		74.30		75.00		75.30		76.00		76.30		77.00		77.30		78.00		78.30		79.00		79.30		80.00		80.30		81.00		81.30		82.00		82.30		83.00		83.30		84.00		84.30		85.00		85.30		86.00		86.30		87.00		87.30		88.00		88.30		89.00		89.30		90.00		90.30		91.00		91.30		92.00		92.30		93.00		93.30		94.00		94.30		95.00		95.30		96.00		96.30		97.00		97.30		98.00		98.30		99.00		99.30		100.00		100.30		101.00		101.30		102.00		102.30		103.00		103.30		104.00		104.30		105.00		105.30		106.00		106.30		107.00		107.30		108.00		108.30		109.00		109.30		110.00		110.30		111.00		111.30		112.00		112.30		113.00		113.30		114.00		114.30		115.00		115.30		116.00		116.30		117.00		117.30		118.00		118.30		119.00		119.30		120.00		120.30		121.00		121.30		122.00		122.30		123.00		123.30		124.00		124.30		125.00		125.30		126.00		126.30		127.00		127.30		128.00		128.30		129.00		129.30		130.00		130.30		131.00		131.30		132.00		132.30		133.00		133.30		134.00		134.30		135.00		135.30		136.00		136.30		137.00		137.30		138.00		138.30		139.00		139.30		140.00		140.30		141.00		141.30		142.00		142.30		143.00		143.30		144.00		144.30		145.00		145.30		146.00		146.30		147.00		147.30		148.00		148.30		149.00		149.30		150.00		150.30		151.00		151.30		152.00		152.30		153.00		153.30		154.00		154.30		155.00		155.30		156.00	
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[illegible]





TIME		DATE		4/27/1965								
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	
8	70.8	9	72.2	10	75.0	11	93.2	12	85.6	13	71.5	
15	94.5	16	77.4	17	96.0	18	85.7	19	94.0	20	85.5	
21	84.5	22	9	24	25	91.2	26	70.6	27	94.8	28	92.0
29	90.2	30	91.0	31	92.4	32	95.1	33	94.4	34	95.8	
35	90.2	37	94.8	38	94.8	39	94.4	40	94.4	41	93.8	
		42	95.8	43	73.8					44	95.8	

TIME	ZLOG	LAST	4/25/1965	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP		
1	14.0	1	11.0	95.0	4	86.0	5	95.0	6	81.7	7	95.0	
8	80.4	7	15.0	10	75.6	11	93.0	12	80.1	13	92.7	14	77.5
15	95.0	16	17.8	11	96.0	18	85.5	19	94.5	20	85.6	21	95.0
22	85.5	23	8	24	0	25	91.0	26	90.0	27	94.9	28	91.1
29	86.0	30	11.4	31	95.8	32	95.5	33	95.1	34	95.0	35	96.4
36	95.5	37	15.0	38	95.5	39	95.5	40	94.5	41	93.9	42	94.0
43	94.5	44	96.0	45	93.9	46	95.5	47	90.0	48	90.0	49	92.0

[illegible]

TIME	2400	LATE	4/29/1965	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	15.0	PI 15.0	PI 15.0	4	79.4	5	92.0	6	79.8	7	91.0
8	79.1	9	78.0	10	85.9	11	85.5	12	75.4	13	94.0
14	90.0	16	79.8	17	94.0	18	81.7	19	93.5	20	83.0
22	82.0	23	0.	24	0.	25	86.2	26	85.2	27	91.3
29	81.0	30	74.7	31	91.8	32	91.8	33	91.5	34	93.0
36	89.0	37	89.0	38	91.5	39	89.5	40	89.5	41	89.3
43	90.8	44	92.8	45	94.0	46	83.5	47	79.8	48	91.9

TIME	100	DATE	4/30/1965	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	90.0	2	94.4	1	9C.5	5	91.0	6	C	7	89.0
8	0.	9	87.5	10	C.	11	89.0	12	0.	13	85.0
15	93.0	16	0.	17	93.0	18	0.	19	92.0	20	0.
22	0.	23	C.	24	C.	25	85.0	26	79.0	27	89.5
29	81.0	30	75.0	31	75.0	32	80.0	33	90.2	34	92.0
36	94.0	37	91.7	38	92.2	39	85.0	40	88.0	41	88.0
43	89.0	44	87.5	45	87.5	46	82.0	47	82.0	48	88.0

[illegible]

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TIME		900		LATE		4/30/1965	
	TEMP.	PI	TEMP.	PI	TEMP.	PI	TEMP.
8	79.0	2	01.0	4	80.0	5	90.0
8	79.0	4	05.0	10	77.6	14	80.5
15	71.8	16	04.3	17	92.0	18	83.6
22	82.7	23	04.5	24	77.0	25	86.2
29	74.0	30	06.8	31	89.5	32	89.4
38	80.0	39	07.0	40	87.9	41	87.9
43	80.6	44	05.5	45	81.0	46	87.0

[illegible]

TIME	PI	TEMP	LATE	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	88.4	7	16.9	3	85.0	4	19.3	5	90.0	6	80.2	7	88.0
8	78.9	9	16.5	10	77.1	11	87.5	12	78.9	13	85.5	14	75.6
15	91.1	16	64.0	17	82.0	18	83.6	19	90.7	20	82.4	21	91.0
22	82.4	23	64.0	24	64.0	25	84.9	26	10.0	27	88.6	28	79.8
29	72.7	30	63.5	31	88.6	32	88.8	33	88.8	34	90.8	35	92.0
36	88.8	37	88.8	38	88.8	39	88.8	40	87.6	41	88.8	42	87.2
43	88.8	44	88.8	45	88.8	46	88.8	47	88.8	48	88.8	49	88.8

TIME 1200		LVL		4/30/1965		PT TEMP		PT TEMP		PT TEMP		PT TEMP	
1	TEMP	1	TEMP	1	TEMP	1	TEMP	1	TEMP	1	TEMP	1	TEMP
1	88.5	2	88.5	3	88.5	4	88.5	5	90.0	6	80.0	7	88.0
8	78.5	9	78.5	10	77.2	11	87.5	12	78.5	13	85.2	14	75.8
15	91.5	16	84.1	17	92.0	18	84.0	19	90.7	20	88.5	21	91.5
22	82.5	23	84.0	24	74.0	25	84.2	26	76.1	27	89.1	28	79.2
29	83.5	30	84.5	31	86.5	32	88.5	33	88.3	34	96.5	35	91.0
36	88.5	37	88.5	38	88.5	39	88.5	40	87.3	41	88.5	42	87.0
43	88.5	44	88.5	45	88.5	46	88.5	47	70.5	48	88.5	49	88.5

TIME 1300		LAMP		4/30/1965		PI TEMP		PI TEMP		PI TEMP		PI TEMP	
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	09.0	2	14.5	4	87.4	4	79.6	5	90.0	6	80.0	7	88.0
8	78.5	9	86.0	10	77.0	11	88.0	12	79.4	13	85.0	14	75.6
15	91.4	16	82.1	17	82.0	18	83.8	19	90.5	20	82.3	21	91.0
22	82.2	23	84.3	24	74.6	25	83.5	26	76.0	27	88.5	28	79.7
29	86.6	30	76.1	31	88.4	32	88.7	33	88.5	34	90.7	35	91.9
36	88.5	37	88.5	38	88.5	39	88.5	40	87.2	41	88.0	42	89.0
43	88.2	44	91.3	45	88.4	46	81.5	47	70.1	48	67.0	49	67.0

TIME		LAUO		LAMP		4/30/1965		PT		TEMP		PT		TEMP		PT		TEMP	
TIME	LAUO	P	I	P	I	P	I	TEMP	P	I	TEMP	P	I	TEMP	P	I	TEMP	P	I
1	89.0	4	79.2	1	89.0	4	79.7	5	90.0	6	80.3	7	88.0						
8	70.5	4	66.0	16	71.0	11	87.0	12	77.8	13	85.5	14	75.0						
15	91.5	4	86.3	17	92.0	18	83.8	19	90.0	20	81.7	21	91.0						
22	82.7	23	0	24	0	25	89.1	26	76.5	27	88.6	28	79.6						
29	82.0	0	10	0	31	88.0	32	88.5	33	86.5	34	90.0	35	91.0					
36	82.0	0	10	0	38	90.0	39	80	87.0	41	88.0	42	86.7						
43	87.5	49	31.5	52	86.5	54	88.0	57	87.8	58	97.0	59	90.0						







[illegible]









TIME 1200		LMI		5/12/1965		PI 1200		PI 1200		PI 1200		PI 1200	
PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP
8	80.9	9	74.0	10	80.0	11	84.0	12	84.0	13	81.0	14	77.9
15	85.1	16	86.4	17	86.6	18	88.1	19	88.0	20	84.1	21	83.5
22	83.6	23	84.0	24	82.1	25	81.4	26	79.0	27	75.0	28	80.5
29	80.4	30	78.1	31	84.9	32	85.0	33	84.0	34	85.1	35	86.6
36	86.1	37	87.0	38	87.1	39	87.2	40	87.2	41	86.1	42	86.0
43	84.4	44	79.0	45	83.1	46	85.0	47	85.1	48	76.2	49	76.0

TIME 1300		LAT		5/12/1965		PT 1600		PT 1600		PT 1600		PT 1600	
PT 1600	PT 1600	PT 1600	PT 1600	PT 1600	PT 1600	PT 1600	PT 1600	PT 1600	PT 1600	PT 1600	PT 1600	PT 1600	PT 1600
8 82.1	9 71.0	10 86.6	11 93.6	12 80.4	13 92.0	14 77.8							
15 95.0	16 10.4	17 93.0	18 91.0	19 94.5	20 85.5	21 92.0							
22 81.7	23 13.0	24 81.4	25 82.0	26 78.0	27 78.0	28 85.0							
29 0.0	30 0.0	31 95.7	32 95.7	33 95.7	34 97.0	35 97.2							
36 97.5	37 97.0	38 95.0	39 95.0	40 96.2	41 96.2	42 96.2							
43 97.6	44 97.5	45 97.5	46 96.8	47 96.2	48 70.2	49 0.0							

TIME 1400		DATE 5/12/1965		PI TEMP		PI TEMP		PI TEMP		PI TEMP		PI TEMP	
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
4	74.4	4	74.4	4	74.4	4	74.4	4	74.4	4	74.4	4	74.4
8	81.2	9	74.0	10	81.2	11	74.0	12	81.2	13	74.0	14	78.0
15	75.5	16	77.1	17	56.0	18	88.9	19	74.0	20	84.9	21	74.0
22	83.4	23	77.0	24	82.0	25	74.0	26	74.2	27	76.9	28	85.0
29	75.1	30	67.0	31	76.0	32	66.1	33	76.6	34	77.2	35	71.5
36	75.0	37	72.2	38	74.0	39	74.0	40	74.0	41	74.0	42	75.0
43	76.0	44	74.0	45	74.4	46	87.1	47	73.0	48	70.3	49	67.0

TIME 1500		LAT		S/L2/1965		PI TEMP		PI TEMP		PI TEMP		PI TEMP	
PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP
8	81.3	9	94.0	10	81.1	11	94.0	12	81.3	13	93.0	14	78.0
15	95.0	16	95.5	17	96.0	18	95.4	19	94.0	20	94.5	21	94.5
22	93.5	23	95.0	24	97.1	25	94.0	26	94.2	27	96.5	28	95.2
29	95.1	30	95.0	31	97.2	32	96.0	33	96.0	34	96.5	35	95.2
36	94.5	37	95.0	38	95.0	39	96.0	40	96.0	41	96.5	42	95.5
43	95.5	44	96.0	45	94.2	46	87.7	47	96.0	48	70.4	49	0.

[illegible]

TIME		1700		DATE		5/12/1965									
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	95.5	2	85.6	3	96.0	4	81.0	5	96.0	6	84.3	7	94.0		
8	81.5	9	94.0	10	81.3	11	94.0	12	81.1	13	92.0	14	79.1		
15	95.0	16	86.6	17	96.0	18	86.0	19	94.4	20	84.3	21	95.0		
22	83.6	23	94.0	24	82.0	25	93.0	26	79.1	27	97.0	28	85.0		
29	95.0	30	96.0	31	76.0	32	95.0	33	77.3	34	86.0	35	85.0		
36	93.0	37	96.0	38	95.0	39	95.3	40	94.5	41	94.5	42	95.0		
43	96.0	44	96.0	45	93.3	46	87.0	47	97.4	48	70.8	49	0.		

[illegible][illegible][illegible]

TYPE		LIFE		5/13/1965							
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
4	10.5	3	9.5	10	11.5	4	10.5	12	11.0	3	10.0
19	10.5	17	11.5	17	10.0	18	11.5	19	11.0	20	10.0
22	11.5	3	10.0	28	11.5	25	11.0	26	11.5	27	11.0
3	10.0	30	11.0	31	10.5	32	10.0	33	10.5	34	10.0
36	11.5	37	11.5	38	10.0	39	10.5	40	11.0	41	10.5
43	10.5	44	11.0	45	11.5	46	10.5	47	10.0	48	10.0

[illegible]

TYPE	AGE	DATE	5/13/1965	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	01.0	2	12.0	1	88.0	4	79.5	5	88.0	6	79.0	7	87.0		
8	75.0	9	74.0	10	75.0	11	84.0	12	75.5	13	78.5	14	71.2		
15	88.0	16	74.0	17	88.0	18	79.5	19	88.0	20	77.0	21	86.0		
22	77.0	23	78.5	24	77.0	25	76.0	26	68.0	27	81.0	28	75.0		
29	75.0	30	75.0	31	75.0	32	75.0	33	75.0	34	75.0	35	75.0		
36	75.0	37	85.0	38	85.0	39	86.0	40	82.0	41	83.0	42	89.0		
43	85.0	44	85.0	45	85.0	46	81.2	47	87.0	48	75.0	49	85.0		

TIME		S.O.		DATE		5/13/1965											
		PI		TEMP		PI		TEMP		PI		TEMP		PI		TEMP	
1		08.00		77.7		1		88.0		6		79.1		7		85.4	
2		17.25		74.0		1		84.0		12		75.6		13		72.1	
3		28.15		70.5		17		78.0		18		79.8		20		75.0	
4		38.15		68.0		28		80.5		25		78.2		27		80.1	
5		48.15		65.0		37		82.0		33		80.8		35		83.0	
6		58.15		62.5		47		83.0		40		83.6		42		86.3	
7		68.15		60.0		55		84.0		47		82.0		48		78.4	
8		78.15		57.5		63		85.0		54		83.0		56		80.0	

TIME LOG		DATE		5/13/1965											
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	95.0	2	93.0	3	95.0	4	82.9	5	95.0	6	94.4	7	92.0		
8	81.5	9	72.0	10	80.7	11	92.0	12	80.7	13	90.0	14	77.7		
15	99.0	16	97.4	17	92.0	18	85.9	19	92.0	20	84.0	21	92.5		
22	83.0	23	93.0	24	82.5	25	90.6	26	79.2	27	96.1	28	85.4		
29	0	30	0	31	95.6	32	96.6	33	96.1	34	96.1	35	96.0		
36	96.2	37	97.2	38	95.5	39	95.0	40	95.5	41	96.0	42	97.6		
43	95.9	44	99.5	45	92.2	46	99.2	47	96.9	48	10.0	49	96.0		

TIME 1700		DATE 5/13/1965									
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
8	95.5	2	82.9	3	96.0	4	81.5	5	95.5	6	85.0
8	81.3	9	84.0	10	81.2	11	93.5	12	80.8	13	91.5
15	94.5	16	86.5	17	96.0	18	85.9	19	93.5	20	84.4
22	84.5	23	96.0	24	84.3	25	91.0	26	79.9	27	96.6
29	74.0	30	61.5	31	96.3	32	97.0	33	97.5	34	95.2
36	96.3	37	93.8	38	95.5	39	94.5	40	93.8	41	95.8
43	96.0	44	93.3	45	92.9	46	96.5	47	93.0	48	95.9

TIME		2300		LAT		5/13/1965									
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	91.0	4	81.4	1	92.0	4	82.1	5	78.0	6	83.0	7	89.0		
8	80.0	9	89.0	10	79.1	11	89.0	12	78.9	13	84.5	14	75.2		
15	91.0	16	83.9	17	92.0	18	84.0	19	90.0	20	81.9	21	90.5		
22	81.6	23	75.0	24	85.5	25	85.0	26	76.4	27	92.0	28	81.5		
29	75.2	30	68.0	31	91.1	32	92.6	33	93.0	34	90.5	35	92.1		
36	92.0	37	90.8	38	90.0	39	88.0	40	88.0	41	89.0	42	90.0		
43	90.0	44	76.0	45	92.0	46	86.1	47	92.0	48	77.0	49	82.0		

TIME	WIND	TEMP	5/16 IN/S	WIND	TEMP	5/16 IN/S	WIND	TEMP	5/16 IN/S	WIND	TEMP	5/16 IN/S	
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	07.0	2	24.9	3	24.0	4	25.0	5	26.0	6	26.9	7	27.0
8	28.4	9	28.0	10	27.3	11	26.0	12	27.3	13	26.8	14	28.7
15	27.5	16	26.5	17	26.0	18	26.5	19	26.0	20	27.4	21	26.0
22	28.5	23	28.5	24	28.7	25	28.5	26	28.3	27	27.6	28	28.9
29	29.0	30	29.0	31	28.7	32	28.8	33	28.8	34	28.6	35	28.8
36	28.0	37	26.0	38	27.7	39	28.8	40	28.3	41	28.0	42	28.8
43	28.0	44	28.0	45	28.1	46	28.0	47	28.0	48	28.0	49	28.0



1960		1965		1970		1975		1980		1985		1990	
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	81.0	2	80.5	3	91.0	4	80.6	5	91.0	6	81.0	7	90.0
8	80.0	9	80.0	10	79.5	11	87.0	12	16.2	13	84.5	14	75.0
15	82.5	16	91.5	17	93.0	18	91.0	19	89.0	20	79.2	21	89.0
22	78.7	23	91.0	24	83.0	25	85.5	26	77.0	27	91.0	28	84.0
29	82.0	30	82.0	31	82.0	32	82.0	33	82.0	34	82.0	35	82.0
36	90.0	37	90.0	38	90.0	39	90.0	40	90.0	41	90.0	42	90.0
43	91.3	44	87.5	45	90.3	46	85.0	47	77.0	48	75.0	49	80.0

TIME		100		DATE		5/16/1965	
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	94.0	2	81.9	3	94.0	4	82.0
5	94.5	6	83.4	7	94.5	8	83.4
8	81.7	9	94.0	10	81.4	11	94.0
12	80.0	13	92.5	14	71.0		
15	94.0	16	84.1	17	95.0	18	83.6
19	94.0	20	82.2	21	94.0		
22	81.6	23	95.0	24	82.3	25	94.2
26	81.0	27	94.0	28	83.3	29	94.0
30	94.0	31	95.0	32	81.0	33	94.0
34	94.0	35	95.0	36	94.0	37	94.0
38	94.0	39	95.0	40	81.0	41	95.0
42	94.0	43	95.0	44	94.0	45	94.0
46	94.0	47	95.0	48	95.0	49	94.0
50	94.0	51	95.0	52	94.0	53	94.0

TIME	TEMP	PI	LATE	5/11/76	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	94.0	4	94.2	3	94.0	4	83.2	5	94.0	6	83.3	7	93.5	
8	94.5	4	94.0	10	80.6	11	94.0	12	80.3	13	92.5	14	77.4	
15	94.5	10	86.1	17	96.0	18	94.0	19	95.0	20	83.8	21	96.0	
22	94.5	10	86.1	23	96.0	24	94.0	25	95.0	26	83.8	27	96.0	
29	94.5	10	86.1	31	95.4	32	95.3	33	95.0	34	94.6	35	94.8	
30	94.5	31	95.8	38	96.2	39	95.0	40	95.0	41	94.8	42	95.2	
43	94.5	44	95.1	45	93.9	46	94.2	47	94.0	48	94.0	49	94.0	

TIME 1400		CAIF		5/18/1965		5/19/1965		5/20/1965		5/21/1965		5/22/1965	
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	94.0	2	80.9	3	93.8	4	94.0	5	94.0	6	94.0	7	93.0
8	79.0	9	94.0	10	80.9	11	94.0	12	94.0	13	94.8	14	77.1
15	93.8	16	95.1	17	95.9	18	94.0	19	94.0	20	93.1	21	94.5
22	83.3	23	76.5	24	81.8	25	94.0	26	94.0	27	93.1	28	94.7
29	80.0	30	94.0	31	94.0	32	94.0	33	94.0	34	94.0	35	94.0
36	95.1	37	95.0	38	95.0	39	94.0	40	94.0	41	94.1	42	94.0
43	94.0	44	89.7	45	91.0	46	94.0	47	95.9	48	94.0	49	94.8















TIME		DATE		5/27/1985							
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	74.1	1	74.2	1	75.5	1	73.0	2	73.3	3	74.2
15	74.0	16	74.2	17	75.0	18	74.8	19	74.0	20	74.0
22	74.0	23	74.0	24	74.0	25	73.0	26	74.0	27	74.0
29	74.0	30	74.0	31	74.0	32	74.0	33	74.0	34	74.0
43	74.0	44	74.0	45	74.0	46	74.0	47	74.0	48	74.0
49	74.0	50	74.0	51	74.0	52	74.0	53	74.0	54	74.0
55	74.0	56	74.0	57	74.0	58	74.0	59	74.0	60	74.0
61	74.0	62	74.0	63	74.0	64	74.0	65	74.0	66	74.0
67	74.0	68	74.0	69	74.0	70	74.0	71	74.0	72	74.0
73	74.0	74	74.0	75	74.0	76	74.0	77	74.0	78	74.0
79	74.0	80	74.0	81	74.0	82	74.0	83	74.0	84	74.0
85	74.0	86	74.0	87	74.0	88	74.0	89	74.0	90	74.0
91	74.0	92	74.0	93	74.0	94	74.0	95	74.0	96	74.0
97	74.0	98	74.0	99	74.0	100	74.0	101	74.0	102	74.0
103	74.0	104	74.0	105	74.0	106	74.0	107	74.0	108	74.0
109	74.0	110	74.0	111	74.0	112	74.0	113	74.0	114	74.0
115	74.0	116	74.0	117	74.0	118	74.0	119	74.0	120	74.0
121	74.0	122	74.0	123	74.0	124	74.0	125	74.0	126	74.0
127	74.0	128	74.0	129	74.0	130	74.0	131	74.0	132	74.0
133	74.0	134	74.0	135	74.0	136	74.0	137	74.0	138	74.0
139	74.0	140	74.0	141	74.0	142	74.0	143	74.0	144	74.0
145	74.0	146	74.0	147	74.0	148	74.0	149	74.0	150	74.0
151	74.0	152	74.0	153	74.0	154	74.0	155	74.0	156	74.0
157	74.0	158	74.0	159	74.0	160	74.0	161	74.0	162	74.0
163	74.0	164	74.0	165	74.0	166	74.0	167	74.0	168	74.0
169	74.0	170	74.0	171	74.0	172	74.0	173	74.0	174	74.0
175	74.0	176	74.0	177	74.0	178	74.0	179	74.0	180	74.0
181	74.0	182	74.0	183	74.0	184	74.0	185	74.0	186	74.0
187	74.0	188	74.0	189	74.0	190	74.0	191	74.0	192	74.0
193	74.0	194	74.0	195	74.0	196	74.0	197	74.0	198	74.0
199	74.0	200	74.0	201	74.0	202	74.0	203	74.0	204	74.0
205	74.0	206	74.0	207	74.0	208	74.0	209	74.0	210	74.0
211	74.0	212	74.0	213	74.0	214	74.0	215	74.0	216	74.0
217	74.0	218	74.0</								



TIME 1100		DATE 5/29/1965		PI TEMP		PI TEMP		PI TEMP		PI TEMP		PI TEMP	
PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP
1 46.3	2 40.3	3 44.0	4 40.7	5 45.0	6 41.6	7 43.8	8 41.6	9 43.8	10 41.6	11 43.8	12 41.6	13 43.8	14 41.6
15 43.8	16 41.6	17 43.8	18 41.6	19 43.8	20 41.6	21 43.8	22 41.6	23 43.8	24 41.6	25 43.8	26 41.6	27 43.8	28 41.6
29 40	30 40	31 40.5	32 40.5	33 40.5	34 40.5	35 40.5	36 40.5	37 40.5	38 40.5	39 40.5	40 40.5	41 40.5	42 40.5
43 40.5	44 40.5	45 40.5	46 40.5	47 40.5	48 40.5	49 40.5	50 40.5	51 40.5	52 40.5	53 40.5	54 40.5	55 40.5	56 40.5
57 40.5	58 40.5	59 40.5	60 40.5	61 40.5	62 40.5	63 40.5	64 40.5	65 40.5	66 40.5	67 40.5	68 40.5	69 40.5	70 40.5
TIME 1800													
PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP
1 43.8	2 40.0	3 44.0	4 40.0	5 44.0	6 41.5	7 43.8	8 41.5	9 43.8	10 41.5	11 43.8	12 41.5	13 43.8	14 41.5
15 43.8	16 41.5	17 43.8	18 41.5	19 43.8	20 41.5	21 43.8	22 41.5	23 43.8	24 41.5	25 43.8	26 41.5	27 43.8	28 41.5
29 40	30 40	31 40.5	32 40.5	33 40.5	34 40.5	35 40.5	36 40.5	37 40.5	38 40.5	39 40.5	40 40.5	41 40.5	42 40.5
43 40.5	44 40.5	45 40.5	46 40.5	47 40.5	48 40.5	49 40.5	50 40.5	51 40.5	52 40.5	53 40.5	54 40.5	55 40.5	56 40.5
57 40.5	58 40.5	59 40.5	60 40.5	61 40.5	62 40.5	63 40.5	64 40.5	65 40.5	66 40.5	67 40.5	68 40.5	69 40.5	70 40.5
TIME 1900													
PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP
1 43.8	2 40.0	3 44.0	4 40.0	5 44.0	6 41.5	7 43.8	8 41.5	9 43.8	10 41.5	11 43.8	12 41.5	13 43.8	14 41.5
15 43.8	16 41.5	17 43.8	18 41.5	19 43.8	20 41.5	21 43.8	22 41.5	23 43.8	24 41.5	25 43.8	26 41.5	27 43.8	28 41.5
29 40	30 40	31 40.5	32 40.5	33 40.5	34 40.5	35 40.5	36 40.5	37 40.5	38 40.5	39 40.5	40 40.5	41 40.5	42 40.5
43 40.5	44 40.5	45 40.5	46 40.5	47 40.5	48 40.5	49 40.5	50 40.5	51 40.5	52 40.5	53 40.5	54 40.5	55 40.5	56 40.5
57 40.5	58 40.5	59 40.5	60 40.5	61 40.5	62 40.5	63 40.5	64 40.5	65 40.5	66 40.5	67 40.5	68 40.5	69 40.5	70 40.5
TIME 5/29/1965													
PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP
1 43.8	2 40.0	3 44.0	4 40.0	5 44.0	6 41.5	7 43.8	8 41.5	9 43.8	10 41.5	11 43.8	12 41.5	13 43.8	14 41.5
15 43.8	16 41.5	17 43.8	18 41.5	19 43.8	20 41.5	21 43.8	22 41.5	23 43.8	24 41.5	25 43.8	26 41.5	27 43.8	28 41.5
29 40	30 40	31 40.5	32 40.5	33 40.5	34 40.5	35 40.5	36 40.5	37 40.5	38 40.5	39 40.5	40 40.5	41 40.5	42 40.5
43 40.5	44 40.5	45 40.5	46 40.5	47 40.5	48 40.5	49 40.5	50 40.5	51 40.5	52 40.5	53 40.5	54 40.5	55 40.5	56 40.5
57 40.5	58 40.5	59 40.5	60 40.5	61 40.5	62 40.5	63 40.5	64 40.5	65 40.5	66 40.5	67 40.5	68 40.5	69 40.5	70 40.5
TIME 2100													
PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP
1 47.5	2 47.6	3 48.4	4 47.8	5 49.0	6 49.0	7 47.5	8 47.5	9 47.5	10 47.5	11 47.5	12 47.5	13 47.5	14 47.5
15 47.5	16 47.5	17 47.5	18 47.5	19 47.5	20 47.5	21 47.5	22 47.5	23 47.5	24 47.5	25 47.5	26 47.5	27 47.5	28 47.5
29 40	30 40	31 40.5	32 40.5	33 40.5	34 40.5	35 40.5	36 40.5	37 40.5	38 40.5	39 40.5	40 40.5	41 40.5	42 40.5
43 40.5	44 40.5	45 40.5	46 40.5	47 40.5	48 40.5	49 40.5	50 40.5	51 40.5	52 40.5	53 40.5	54 40.5	55 40.5	56 40.5
57 40.5	58 40.5	59 40.5	60 40.5	61 40.5	62 40.5	63 40.5	64 40.5	65 40.5	66 40.5	67 40.5	68 40.5	69 40.5	70 40.5
TIME 2200													
PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP
1 47.5	2 48.5	3 48.4	4 48.6	5 48.0	6 48.0	7 47.5	8 47.5	9 47.5	10 47.5	11 47.5	12 47.5	13 47.5	14 47.5
15 47.5	16 47.5	17 47.5	18 47.5	19 47.5	20 47.5	21 47.5	22 47.5	23 47.5	24 47.5	25 47.5	26 47.5	27 47.5	28 47.5
29 40	30 40	31 40.5	32 40.5	33 40.5	34 40.5	35 40.5	36 40.5	37 40.5	38 40.5	39 40.5	40 40.5	41 40.5	42 40.5
43 40.5	44 40.5	45 40.5	46 40.5	47 40.5	48 40.5	49 40.5	50 40.5	51 40.5	52 40.5	53 40.5	54 40.5	55 40.5	56 40.5
57 40.5	58 40.5	59 40.5	60 40.5	61 40.5	62 40.5	63 40.5	64 40.5	65 40.5	66 40.5	67 40.5	68 40.5	69 40.5	70 40.5

[illegible][illegible]





TIME		DATE		A/2/1965											
PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP
1	43.0	2	40.4	3	41.0	4	40.9	5	42.5	6	40.9	7	42.5		
8	40.5	9	42.0	10	49.0	11	42.0	12	48.2	13	42.4	14	47.5		
15	42.4	16	42.3	17	42.0	18	41.0	19	43.0	20	40.7	21	42.2		
22	49.5	23	45.0	24	40.5	25	42.2	26	40.0	27	42.0	28	40.0		
29	43.0	30	43.0	31	43.0	32	43.0	33	43.4	34	43.3	35	43.2		
36	43.1	37	43.7	38	43.6	39	43.5	40	43.5	41	43.3	42	43.3		
43	43.8	44	45.4	45	43.4	46	47.6	47	49.2	48	42.0	49	41.9		

TIME 2200		DATE 6/2/1965									
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	87.0	2	78.9	3	87.4	4	79.3	5	89.0	6	80.4
8	77.7	9	85.0	10	76.8	11	83.0	12	75.4	13	81.4
15	88.0	16	80.4	17	87.0	18	78.9	19	86.5	20	78.0
22	78.2	23	86.0	24	79.4	25	82.0	26	76.2	27	87.8
30	86.0	31	87.8	32	85.0	33	88.1	34	85.0	35	88.0
36	85.3	37	87.8	38	87.4	39	87.4	40	81.5	41	86.3
43	87.4	44	85.4	45	86.3	46	85.3	47	88.0	48	72.0
49		50		51		52		53		54	71.0

JPL		ADM		DATE		AZ		3/1965							
P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP
8	75.4	7	76.0	1	86.5	4	77.3	5	85.5	6	77.8	7	82.0		
8	75.4	4	76.0	10	74.2	11	78.0	12	75.4	13	75.5	14	73.0		
15	85.0	16	77.8	17	84.0	18	81.0	19	84.0	20	75.8	21	82.3		
22	81.0	23	76.0	24	81.0	25	76.0	26	81.0	27	77.7	28	81.0		
29	81.0	30	76.0	31	84.0	32	85.0	33	86.1	34	87.7	35	84.6		
36	84.0	37	84.0	38	83.7	39	83.4	40	82.3	41	80.9	42	82.2		
43	81.0	44	81.0	45	82.0	46	81.9	47	85.1	48	76.0	49	71.0		

TIME		DATE		4/3/1963											
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	90.0	2	78.4	3	90.0	4	79.0	5	90.5	6	79.4	7	89.0		
8	78.9	9	88.5	10	77.3	11	88.0	12	76.4	13	88.0	14	76.0		
15	90.0	16	80.0	17	83.3	18	79.4	19	85.2	20	78.7	21	89.0		
22	90.0	23	80.0	24	80.0	25	88.0	26	77.7	27	80.0	28	80.0		
29	90.0	30	80.0	31	91.3	32	91.3	33	90.8	34	91.3	35	90.4		
36	91.0	37	90.7	38	90.3	39	90.3	40	90.2	41	90.0	42	90.1		
43	91.2	44	88.0	45	90.3	46	88.1	47	91.0	48	70.9	49	70.2		







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LINE	ADD	DATE	#	7/19/65	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP
1	86.2	2	75.4	3	87.6	4	75.8	5	88.0	6	86.6	7	84.0	
8	77.4	9	82.0	10	76.1	11	82.5	12	76.5	13	76.6	14	73.4	
15	88.0	16	85.0	17	86.0	18	75.6	19	88.2	20	79.2	21	86.0	
22	79.0	23	80.5	24	79.0	25	75.7	26	73.6	27	87.0	28	82.2	
29	80.0	30	82.0	31	82.0	32	86.0	33	86.0	34	86.0	35	87.8	
36	88.0	37	87.8	38	87.1	39	86.0	40	85.0	41	83.6	42	82.0	
43	88.0	44	88.8	45	85.3	46	83.4	47	88.0	48	74.0	49	73.3	

TIME		LOU		LAIS		A/ 7/15/65									
PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP
1	91.5	2	82.0	3	91.5	4	82.3	5	92.0	6	82.9	7	90.5		
8	80.4	9	90.0	10	75.4	11	90.0	12	79.4	13	80.0	14	77.1		
15	91.5	16	82.5	17	91.5	18	82.5	19	91.6	20	91.5	21	91.0		
22	81.5	23	91.0	24	81.5	25	89.6	26	79.2	27	93.0	28	88.3		
29	84.0	30	54.0	31	82.8	32	92.8	33	92.2	34	92.4	35	92.0		
36	91.5	37	91.5	38	92.3	39	92.3	40	91.8	41	91.1	42	90.0		
43	92.7	44	88.8	45	91.8	46	91.8	47	93.3	48	93.3	49	93.0		

LINE	LOGO	LA11	6/27/1565	LINE	LOGO	LA11	6/27/1565
1	TEMP	1	TEMP	1	TEMP	1	TEMP
1	54.0	2	41.5	1	54.0	4	83.5
8	61.5	4	43.5	11	93.5	12	80.6
15	54.0	16	43.0	18	83.2	19	54.0
22	62.0	23	43.0	24	82.1	25	93.0
28	54.0	29	43.0	30	83.2	31	93.0
35	54.0	36	43.0	37	94.9	38	94.9
42	54.0	43	43.0	44	88.2	45	95.1
48	54.0	49	43.0	50	94.9	51	94.0
54	54.0	55	43.0	56	88.2	57	95.1
60	54.0	61	43.0	62	94.9	63	94.0
66	54.0	67	43.0	68	88.2	69	95.1
72	54.0	73	43.0	74	94.9	75	94.0
78	54.0	79	43.0	80	88.2	81	95.1
84	54.0	85	43.0	86	94.9	87	94.0
90	54.0	91	43.0	92	88.2	93	95.1
96	54.0	97	43.0	98	94.9	99	94.0
102	54.0	103	43.0	104	88.2	105	95.1
108	54.0	109	43.0	110	94.9	111	94.0
114	54.0	115	43.0	116	88.2	117	95.1
120	54.0	121	43.0	122	94.9	123	94.0
126	54.0	127	43.0	128	88.2	129	95.1
132	54.0	133	43.0	134	94.9	135	94.0
138	54.0	139	43.0	140	88.2	141	95.1
144	54.0	145	43.0	146	94.9	147	94.0
150	54.0	151	43.0	152	88.2	153	95.1
156	54.0	157	43.0	158	94.9	159	94.0
162	54.0	163	43.0	164	88.2	165	95.1
168	54.0	169	43.0	170	94.9	171	94.0
174	54.0	175	43.0	176	88.2	177	95.1
180	54.0	181	43.0	182	94.9	183	94.0
186	54.0	187	43.0	188	88.2	189	95.1
192	54.0	193	43.0	194	94.9	195	94.0
198	54.0	199	43.0	200	88.2	201	95.1
204	54.0	205	43.0	206	94.9	207	94.0
210	54.0	211	43.0	212	88.2	213	95.1
216	54.0	217	43.0	218	94.9	219	94.0
222	54.0	223	43.0	224	88.2	225	95.1
228	54.0	229	43.0	230	94.9	231	94.0
234	54.0	235	43.0	236	88.2	237	95.1
240	54.0	241	43.0	242	94.9	243	94.0
246	54.0	247	43.0	248	88.2	249	95.1
252	54.0	253	43.0	254	94.9	255	94.0
258	54.0	259	43.0	260	88.2	261	95.1
264	54.0	265	43.0	266	94.9	267	94.0
270	54.0	271	43.0	272	88.2	273	95.1
276	54.0	277	43.0	278	94.9	279	94.0
282	54.0	283	43.0	284	88.2	285	95.1
288	54.0	289	43.0	290	94.9	291	94.0
294	54.0						

[illegible][illegible]

LINE	IDUN	LAIE	6/	M/1965	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	PI TEMP	
1	52.4	4	3.4	1	91.8	4	82.2	5	52.6	6	82.5	7	90.8
8	80.2	3	16.0	10	70.7	11	90.0	12	78.9	13	88.7	14	70.6
12	51.2	10	22.5	17	91.0	18	82.0	19	91.2	20	81.2	21	91.5
22	61.7	3	11.0	24	81.5	25	88.3	26	78.6	27	93.1	28	85.6
29	51.2	17	1.0	36	91.9	37	92.0	38	91.0	39	91.0	40	91.1
36	92.6	37	1.0	42	92.6	43	92.6	44	91.4	45	91.2	46	91.1
43	92.3	44	32.0	45	92.3	46	87.2	47	93.3	48	74.0	49	73.4

[illegible]



LINE		2400		DATE		4/10/1545											
PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP
1	90.2	2	83.5	3	90.1	4	84.0	5	90.0	6	83.7	7	88.0				
8	81.1	9	86.5	10	84.4	11	86.5	12	81.0	13	75.5	14	72.7				
15	89.4	16	81.7	17	85.5	18	82.7	19	88.0	20	88.0	21	88.0				
22	81.5	23	89.5	24	85.5	25	76.7	26	73.4	27	91.6	28	86.0				
29	81.0	30	81.0	31	81.2	32	81.2	33	91.2	34	81.2	35	90.1				
36	90.9	37	88.4	38	89.0	39	89.1	40	84.5	41	86.9	42	88.0				
43	88.0	44	86.0	45	83.5	46	82.9	47	84.6	48	73.9	49	72.9				

LINE	AMU	FAIR	6/11/1505	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP	PT	TEMP
1	69.4	4	11.3	9	96.5	4	83.5	5	90.1	6	84.0	7	87.2
8	60.5	4	36.5	10	81.0	11	86.0	12	80.0	13	76.0	14	72.8
12	64.4	10	11.1	17	85.5	18	82.5	19	88.0	20	81.0	21	88.0
22	61.2	3	65.5	24	83.1	25	76.5	26	73.0	27	91.0	28	85.5
30	61.0	3	66.8	32	84.0	33	59.0	34	66.0	35	70.0	36	70.0
40	60.5	7	35.0	38	86.9	39	89.0	40	84.0	41	86.5	42	88.0
43	61.2	55	25.0	42	83.3	43	82.7	44	84.0	45	78.5	46	71.7

[illegible]

LINE INVT		LAL		6/11/1505											
PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP
1	0.0	4	24.0	1	26.8	9	25.9	4	24.4	6	25.1	4	25.1	7	28.0
8	0.1	5	26.5	10	26.8	11	25.9	12	28.0	13	26.5	14	23.4		
15	29.9	16	23.3	17	25.0	18	23.3	19	27.6	20	26.6	21	28.5		
22	29.8	23	26.0	24	25.5	25	27.5	26	24.4	27	26.9	28	26.5		
29	30.0	30	26.0	31	28.0	32	28.0	33	26.0	34	26.0	35	26.0		
36	30.1	37	30.0	38	27.6	39	27.2	40	28.1	41	27.4	42	27.0		
43	30.0	44	27.5	45	28.2	46	25.4	47	26.1	48	27.3	49	27.3		

LINE		NAME		6/12/1565							
P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP
1	TEMP	2	TEMP	3	TEMP	4	TEMP	5	TEMP	6	TEMP
8	75.1	1	75.5	11	75.4	11	75.0	12	76.0	13	76.0
15	76.0	15	76.5	17	76.5	18	76.2	19	76.5	21	76.0
22	76.5	22	76.5	24	76.5	25	76.5	26	76.5	27	76.5
29	76.5	29	76.5	31	76.5	32	76.5	33	76.5	34	76.5
36	76.5	36	76.5	38	76.5	39	76.0	40	76.0	41	76.0
43	76.5	43	76.5	45	76.0	46	76.0	47	76.5	48	76.0
LINE		NAME		6/12/1565							
P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP
1	TEMP	2	TEMP	3	TEMP	4	TEMP	5	TEMP	6	TEMP
8	76.0	1	76.0	11	75.5	11	75.0	12	76.0	13	76.0
15	76.0	15	76.5	17	76.5	18	76.4	19	76.5	21	76.0
22	76.5	22	76.5	24	76.5	25	76.5	26	76.0	27	76.0
29	76.5	29	76.5	31	76.5	32	76.5	33	76.5	34	76.5
36	76.5	36	76.5	38	76.5	39	76.7	40	76.0	41	76.7
43	76.5	43	76.5	45	76.0	46	76.5	47	77.0	48	76.5
LINE		NAME		6/12/1565							
P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP
1	TEMP	2	TEMP	3	TEMP	4	TEMP	5	TEMP	6	TEMP
8	76.1	1	76.0	11	76.3	11	76.5	12	77.0	13	80.2
15	76.0	15	76.5	17	76.5	18	82.2	19	82.5	20	75.7
22	80.5	22	80.0	24	80.0	25	80.8	26	76.0	27	86.0
29	86.0	29	86.0	31	86.0	32	86.3	33	86.0	34	82.5
36	86.0	36	87.5	38	86.5	39	88.5	40	83.7	41	83.6
43	86.5	43	86.5	45	83.5	46	82.5	47	83.7	48	71.6
LINE		NAME		6/12/1565							
P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP
1	TEMP	2	TEMP	3	TEMP	4	TEMP	5	TEMP	6	TEMP
8	77.1	1	76.5	11	77.1	11	86.2	12	79.4	13	86.0
15	80.0	15	80.0	17	96.0	18	82.8	19	88.0	20	80.0
22	80.5	22	80.0	24	75.5	25	93.8	26	77.1	27	87.5
29	86.0	29	86.0	31	85.8	32	86.0	33	86.0	34	86.0
36	86.0	36	86.0	38	85.8	39	90.0	40	86.1	41	85.9
43	87.0	43	89.5	45	85.5	46	83.8	47	83.5	48	71.8
LINE		NAME		6/12/1565							
P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP
1	TEMP	2	TEMP	3	TEMP	4	TEMP	5	TEMP	6	TEMP
8	77.8	1	77.0	11	88.6	12	79.4	13	86.0	14	76.2
15	91.0	16	92.5	17	90.5	18	83.0	19	90.0	20	81.5
22	81.5	23	80.0	24	80.3	25	86.1	26	77.1	27	85.0
29	86.0	29	86.0	31	85.8	32	86.0	33	86.0	34	86.0
36	86.0	36	86.0	38	86.0	39	91.0	40	86.0	41	86.0
43	86.0	43	86.5	45	87.6	46	84.8	47	86.0	48	71.8
LINE		NAME		6/12/1565							
P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP	P1	TEMP
1	TEMP	2	TEMP	3	TEMP	4	TEMP	5	TEMP	6	TEMP
8	77.8	9	90.0	11	78.0	11	90.0	12	78.3	13	80.6
15	92.0	16	93.0	17	92.0	18	84.2	19	91.2	20	82.0
22	82.0	23	92.0	24	80.3	25	90.5	26	78.5	27	91.5
29	86.0	30	86.0	31	85.2	32	91.8	33	91.5	34	92.1
36	91.8	37	91.8	38	91.8	39	93.0	40	91.0	41	90.0
43	91.5	44	88.2	45	90.8	46	89.5	47	90.0	48	72.0

TEMP		LATE		6/12/1965		TEMP		PI		TEMP		PI		TEMP		PI			
1	93.0	1	81.0	3	91.5	4	81.6	5	96.0	6	82.1	7	93.0	8	93.0	9	93.0		
8	90.0	9	82.5	10	79.6	11	93.0	12	81.0	13	91.4	14	77.6	15	93.0	16	93.0		
22	93.0	16	93.0	17	95.5	18	87.6	19	95.0	20	85.3	21	96.0	22	96.0	23	96.0		
24	95.0	24	95.0	25	91.8	26	80.5	27	94.0	28	84.0	29	96.0	30	96.0	31	96.0		
29	96.0	30	96.0	31	94.5	32	96.5	33	96.0	34	95.0	35	96.0	36	96.0	37	96.0		
38	97.0	39	95.5	40	96.0	41	96.0	42	94.0	43	93.0	44	92.1	45	93.1	46	93.1		
47	94.0	48	94.0	49	92.8	50	88.6	51	96.0	52	96.0	53	96.0	54	96.0	55	96.0		
LATE 6/12/1965																			
1	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP	PI	TEMP		
1	92.6	2	81.0	3	92.8	4	81.8	5	93.0	6	81.9	7	92.0	8	92.0	9	92.0	10	92.0
8	79.4	9	81.0	10	78.8	11	92.0	12	80.3	13	91.0	14	77.9	15	93.0	16	93.0	17	93.0
18	96.0	19	96.0	20	93.0	21	86.6	22	95.3	23	85.0	24	95.0	25	95.0	26	95.0	27	95.0
28	95.1	29	96.0	30	94.0	31	94.1	32	96.0	33	96.0	34	96.0	35	96.0	36	96.0	37	96.0
38	96.0	39	96.0	40	96.0	41	96.0	42	96.0	43	96.0	44	96.0	45	96.0	46	96.0	47	96.0
48	96.0	49	96.0	50	96.0	51	96.0	52	96.0	53	96.0	54	96.0	55	96.0	56	96.0	57	96.0
58	96.0	59	96.0	60	96.0	61	96.0	62	96.0	63	96.0	64	96.0	65	96.0	66	96.0	67	96.0
68	96.0	69	96.0	70	96.0	71	96.0	72	96.0	73	96.0	74	96.0	75	96.0	76	96.0	77	96.0
78	96.0	79	96.0	80	96.0	81	96.0	82	96.0	83	96.0	84	96.0	85	96.0	86	96.0	87	96.0
88	96.0	89	96.0	90	96.0	91	96.0	92	96.0	93	96.0	94	96.0	95	96.0	96	96.0	97	96.0
98	96.0	99	96.0	100	96.0	101	96.0	102	96.0	103	96.0	104	96.0	105	96.0	106	96.0	107	96.0
108	96.0	109	96.0	110	96.0	111	96.0	112	96.0	113	96.0	114	96.0	115	96.0	116	96.0	117	96.0
118	96.0	119	96.0	120	96.0	121	96.0	122	96.0	123	96.0	124	96.0	125	96.0	126	96.0	127	96.0
128	96.0	129	96.0	130	96.0	131	96.0	132	96.0	133	96.0	134	96.0	135	96.0	136	96.0	137	96.0

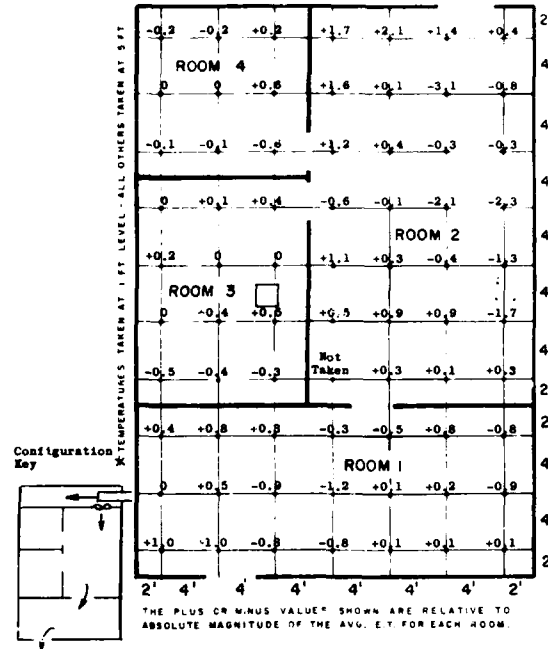




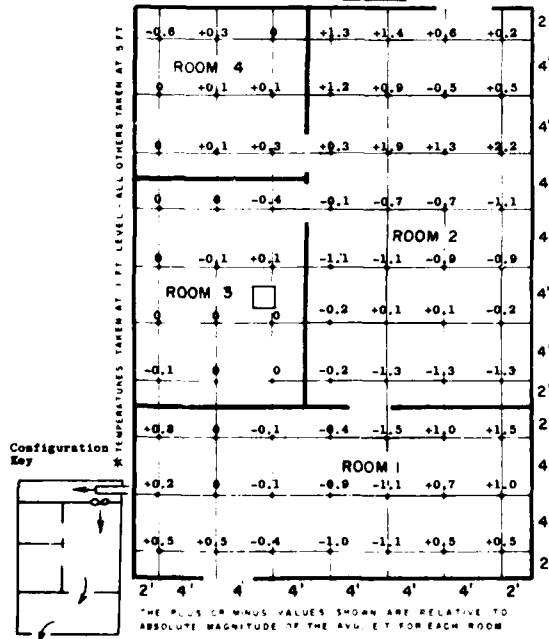
# APPENDIX C

## Effective Temperature Distribution

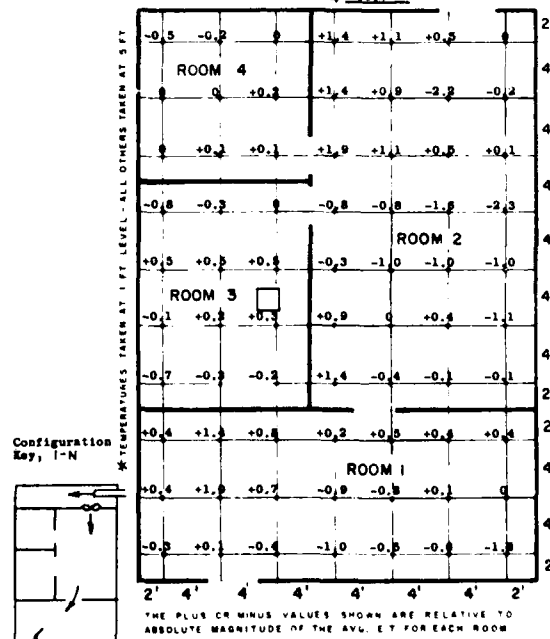
CONFIGURATION NO. 1-N  
TEST NO. 1 (Minimum Shelter Response)  
VENTILATION RATE 13.2 cfm/occ  
AVG. SHELTER E.T. 83.3°  
AVG. E.T. OF ROOM  
1 83.5  
2 80.9  
3 86.3  
4 84.4



CONFIGURATION NO. 1-N  
TEST NO. 1 (Maximum Shelter Response)  
VENTILATION RATE 13.2 cfm/occ  
AVG. SHELTER E.T. 89°  
AVG. E.T. OF ROOM  
1 87.3  
2 87.7  
3 92.4  
4 91.2

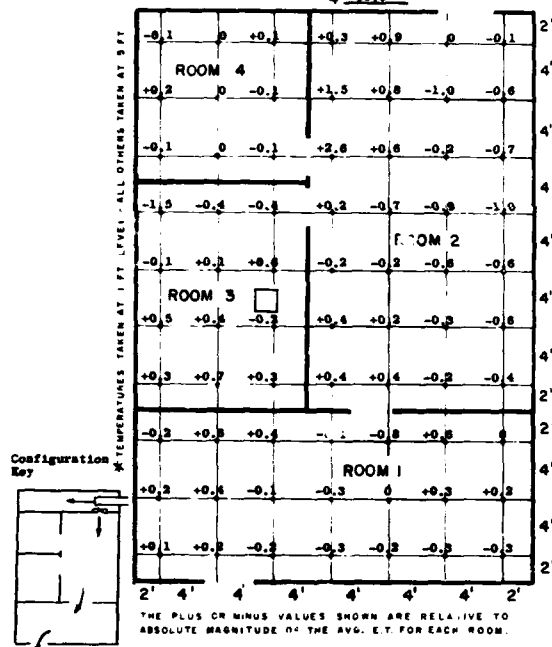


CONFIGURATION NO. 2-N  
TEST NO. 2  
VENTILATION RATE 13.27 cfm/occ  
AVG. SHELTER E.T. 83.6°  
AVG. E.T. OF ROOM  
1 83.4  
2 81.1  
3 86.3  
4 85.1



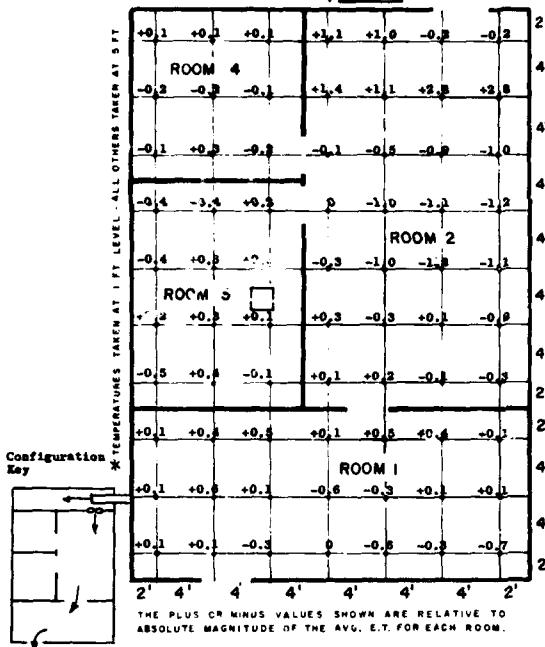
CONFIGURATION NO. 1-M  
 TEST NO. 3  
 VENTILATION RATE 12.5 cfm/occ  
 AVG. SHELTER E.T. 85.3°  
 AVG. E.T. OF ROOM

1 85.3  
 2 83.6  
 3 87.4  
 4 85.5



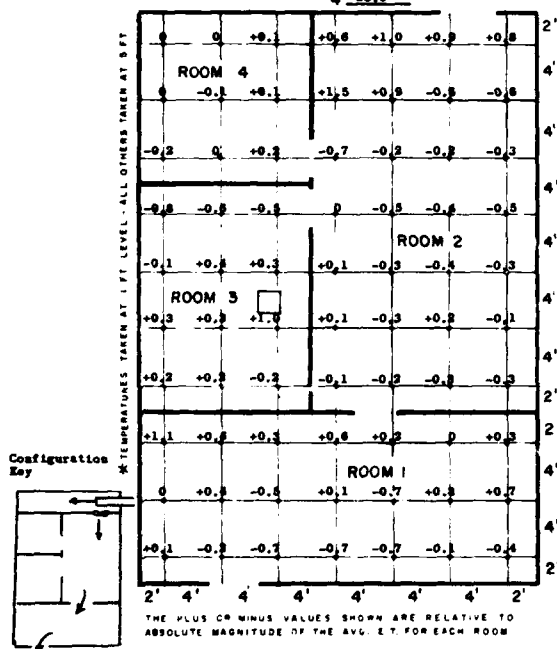
CONFIGURATION NO. 1-M  
 TEST NO. 4  
 VENTILATION RATE 13.4 cfm/occ  
 AVG. SHELTER E.T. 88.2°  
 AVG. E.T. OF ROOM

1 88.1  
 2 86.8  
 3 90.9  
 4 88.2



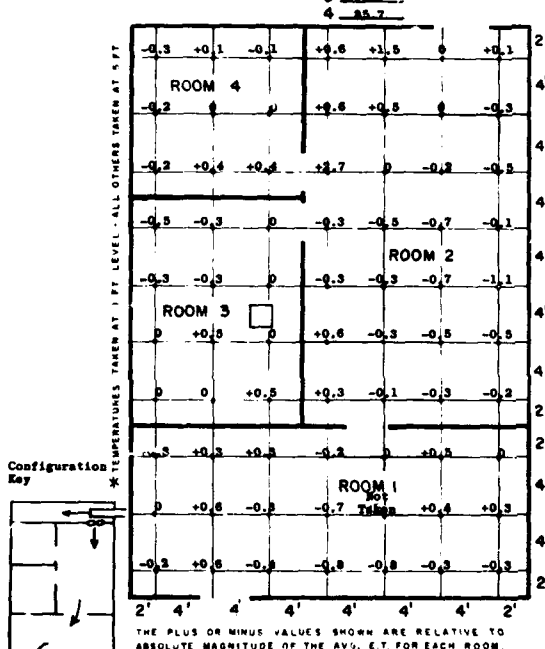
CONFIGURATION NO. 1-M  
 TEST NO. 5  
 VENTILATION RATE 17.81 cfm/occ  
 AVG. SHELTER E.T. 87.4°  
 AVG. E.T. OF ROOM

1 86.7  
 2 88.6  
 3 90.2  
 4 88.6



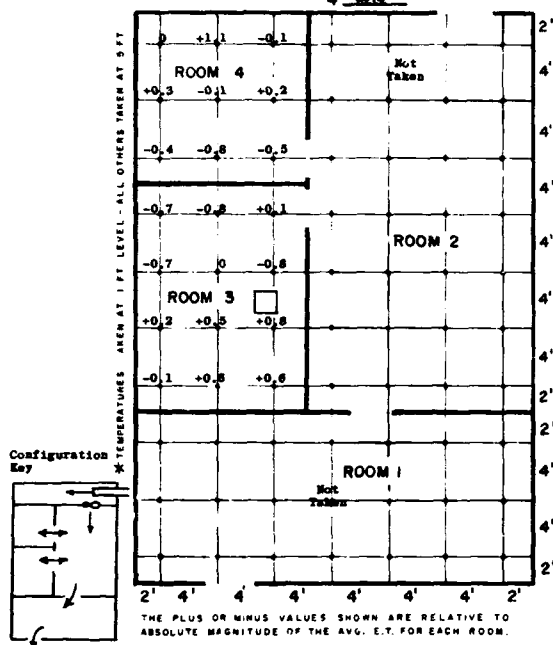
CONFIGURATION NO. 1-M  
 TEST NO. 6  
 VENTILATION RATE 17.9 cfm/occ  
 AVG. SHELTER E.T. 84.2°  
 AVG. E.T. OF ROOM

1 84.2  
 2 86.5  
 3 88.3  
 4 85.7



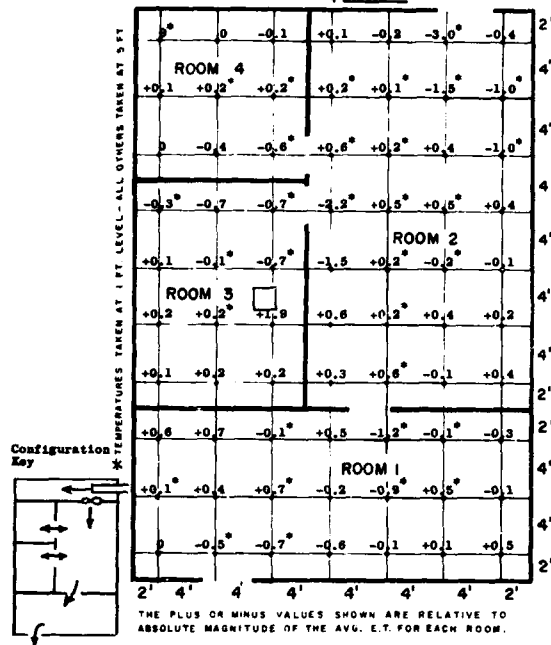
CONFIGURATION NO. 1-P  
 TEST NO. 18  
 VENTILATION RATE 13.3 cfm/occ  
 AVG. SHELTER E.T. 83.8°  
 AVG. E.T. OF ROOM

1 84.3  
 2 82.8  
 3 83.4  
 4 82.8



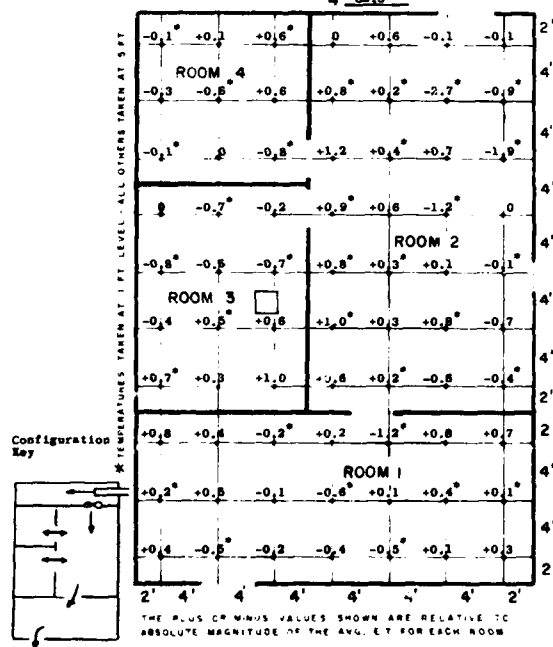
CONFIGURATION NO. 1-P  
 TEST NO. 19  
 VENTILATION RATE 17.91 cfm/occ  
 AVG. SHELTER E.T. 83.8°  
 AVG. E.T. OF ROOM

1 84.3  
 2 82.8  
 3 85.0  
 4 84.4



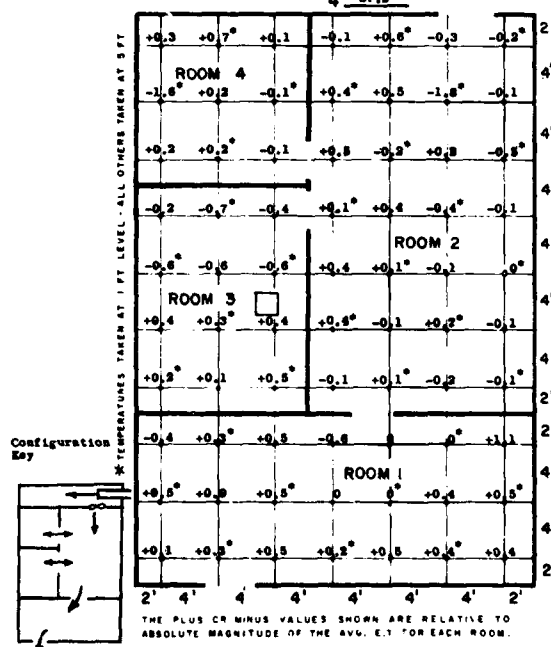
CONFIGURATION NO. 1-P  
 TEST NO. 19  
 VENTILATION RATE 19.0 cfm/occ  
 AVG. SHELTER E.T. 81.1°  
 AVG. E.T. OF ROOM

1 81.5  
 2 79.7  
 3 82.2  
 4 82.3

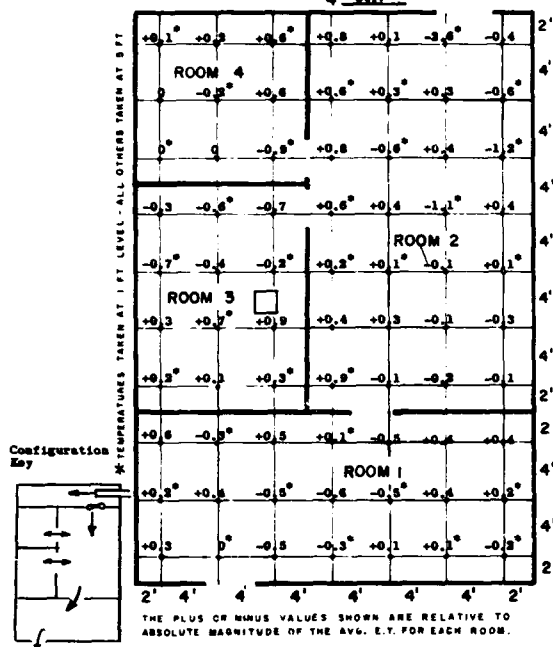


CONFIGURATION NO. 1-P  
 TEST NO. 20  
 VENTILATION RATE 22.5 cfm/occ  
 AVG. SHELTER E.T. 86.6°  
 AVG. E.T. OF ROOM

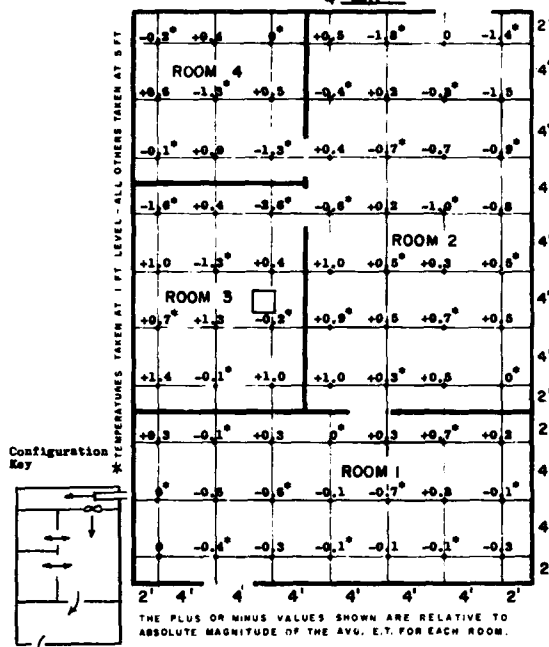
1 86.7  
 2 85.9  
 3 87.4  
 4 87.3



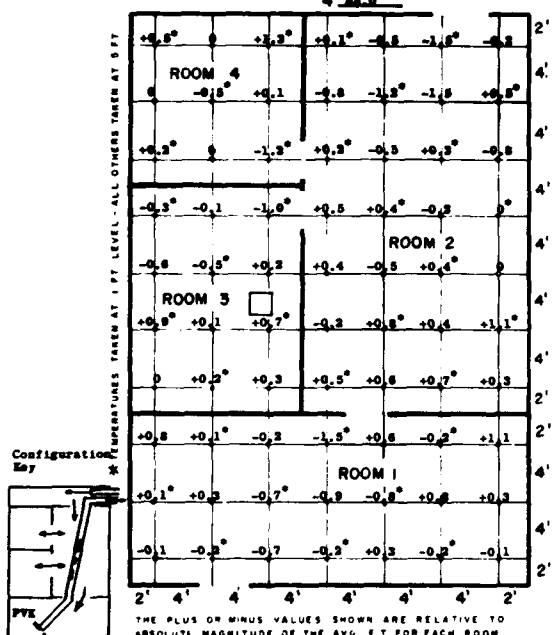
CONFIGURATION NO. 1-P  
 TEST NO. 31  
 VENTILATION RATE 22.5 cfm/occ  
 AVG. SHELTER E.T. 83.9°  
 AVG. E.T. OF ROOM 1 83.9  
 2 88.8  
 3 84.8  
 4 84.7



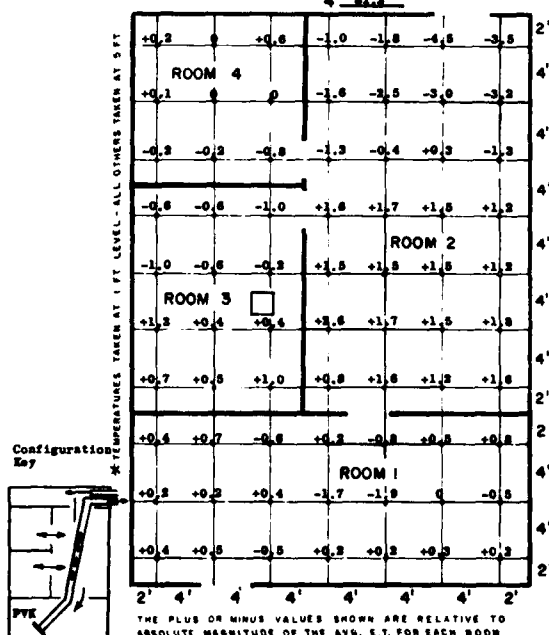
CONFIGURATION NO. 1-P  
 TEST NO. 32  
 VENTILATION RATE 13.3 cfm/occ  
 AVG. SHELTER E.T. 87.8°  
 AVG. E.T. OF ROOM 1 88.5  
 2 86.5  
 3 80.3  
 4 88.7



CONFIGURATION NO. 2-P  
 TEST NO. 37 (Maximum Shelter Response)  
 VENTILATION RATE 18  
 AVG. SHELTER E.T. 82.9°  
 AVG. E.T. OF ROOM 1 84.8  
 2 85.3  
 3 85.3  
 4 84.8

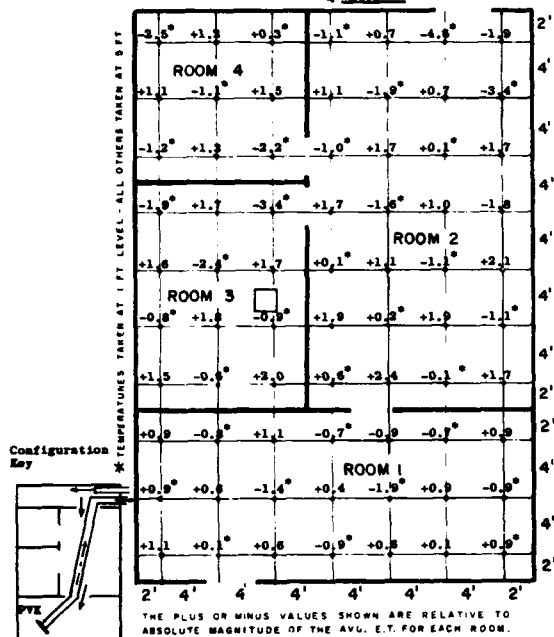


CONFIGURATION NO. 2-P  
 TEST NO. 38  
 VENTILATION RATE 10.8 cfm/occ  
 AVG. SHELTER E.T. 85.3°  
 AVG. E.T. OF ROOM 1 84.9  
 2 81.0  
 3 82.8  
 4 81.8



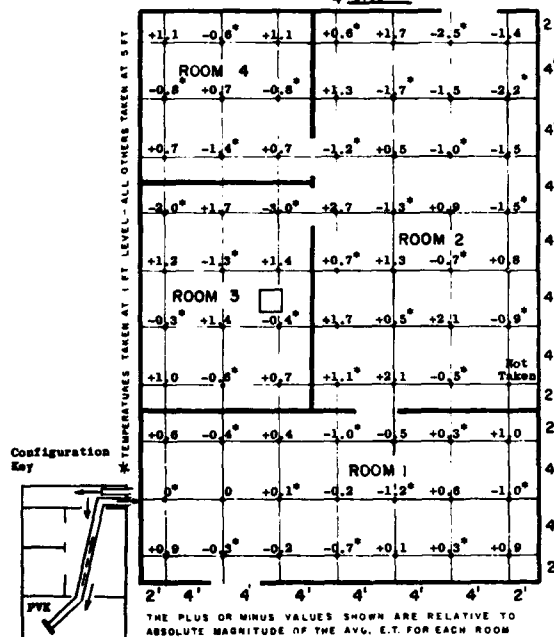
CONFIGURATION NO. 2-M  
 TEST NO. 39  
 VENTILATION RATE 10.5 cfm/occ  
 AVG. SHELTER E.T. 83.1°  
 AVG. E.T. OF ROOM

1 85.3  
 2 83.4  
 3 85.9  
 4 84.0



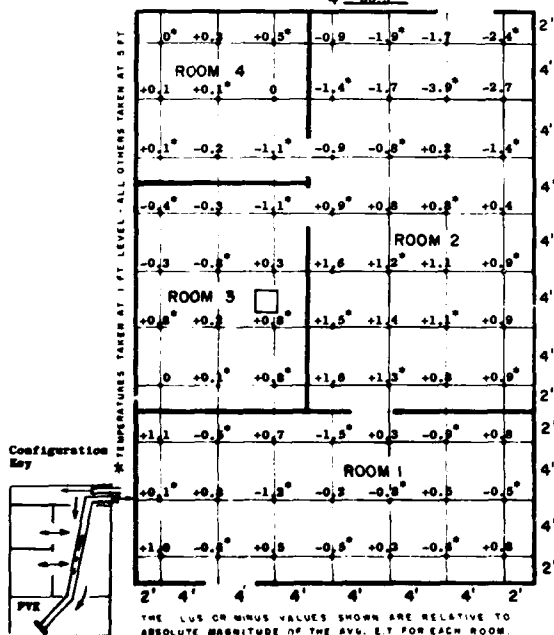
CONFIGURATION NO. 2-M  
 TEST NO. 40  
 VENTILATION RATE 10.5 cfm/occ  
 AVG. SHELTER E.T. 85.5°  
 AVG. E.T. OF ROOM

1 87.5  
 2 84.5  
 3 88.0  
 4 87.0



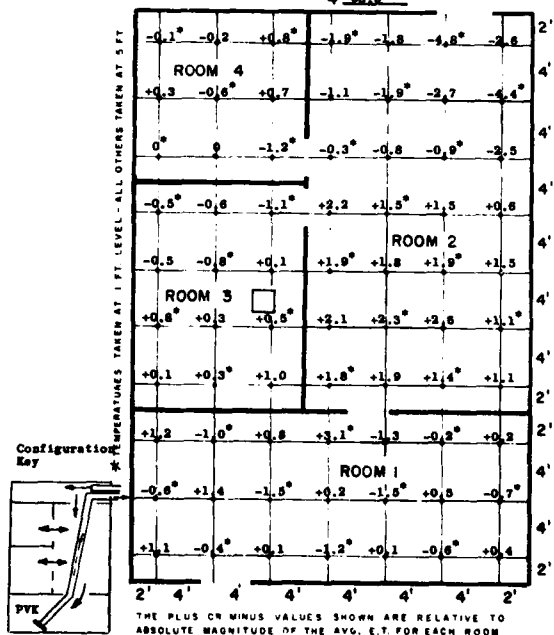
CONFIGURATION NO. 2-P  
 TEST NO. 41  
 VENTILATION RATE 10.5 cfm/occ  
 AVG. SHELTER E.T. 86.2°  
 AVG. E.T. OF ROOM

1 88.3  
 2 85.0  
 3 87.3  
 4 85.3



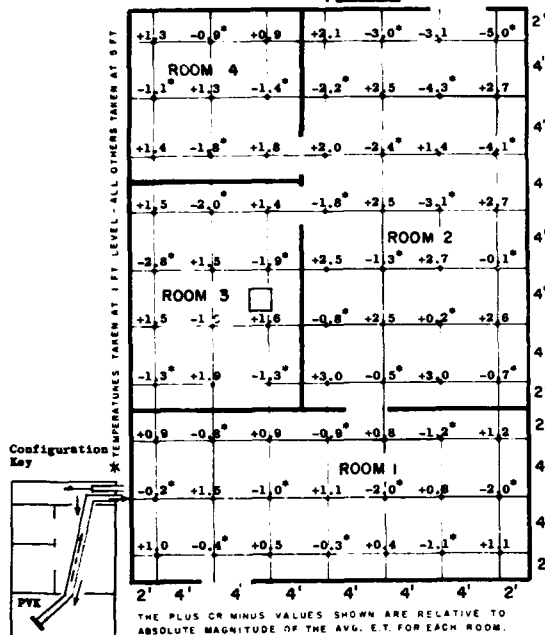
CONFIGURATION NO. 2-P  
 TEST NO. 42 (R)  
 VENTILATION RATE 8.0 cfm/occ  
 AVG. SHELTER E.T. 84.5°  
 AVG. E.T. OF ROOM

1 87.1  
 2 82.9  
 3 86.2  
 4 83.6



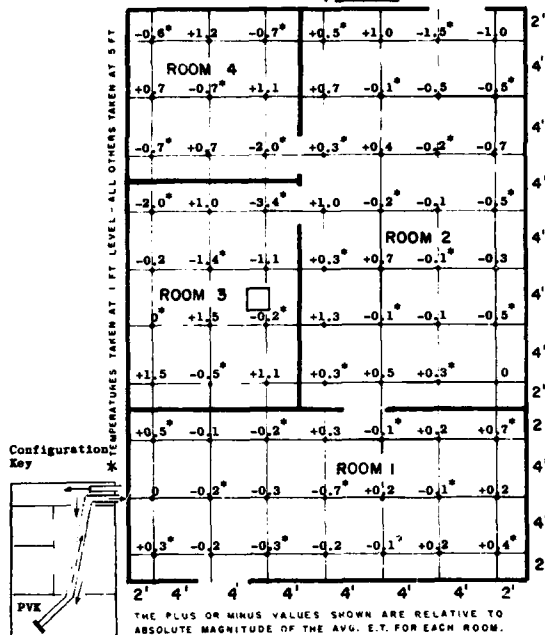
CONFIGURATION NO. 2-N  
 TEST NO. 43  
 VENTILATION RATE 8.0 cfm/occ  
 AVG. SHELTER E.T. 84.2°  
 AVG. E.T. OF ROOM

1 87.4  
 2 84.4  
 3 86.4  
 4 85.9



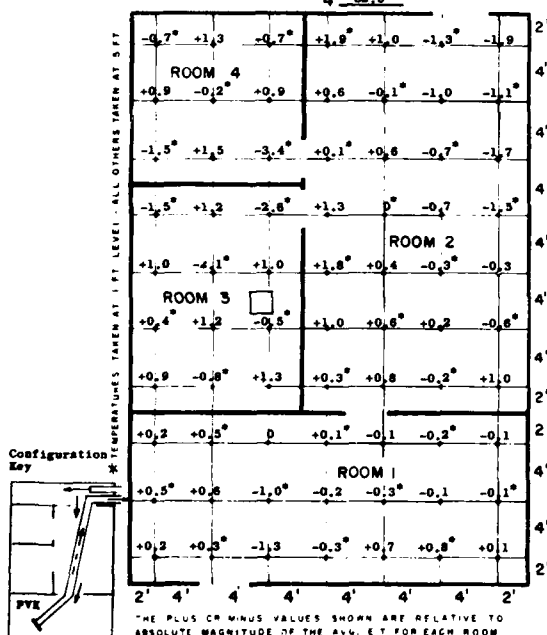
CONFIGURATION NO. 2-N  
 TEST NO. 44  
 VENTILATION RATE 22.1 cfm/occ  
 AVG. SHELTER E.T. 87.1°  
 AVG. E.T. OF ROOM

1 86.5  
 2 85.7  
 3 90.2  
 4 88.6



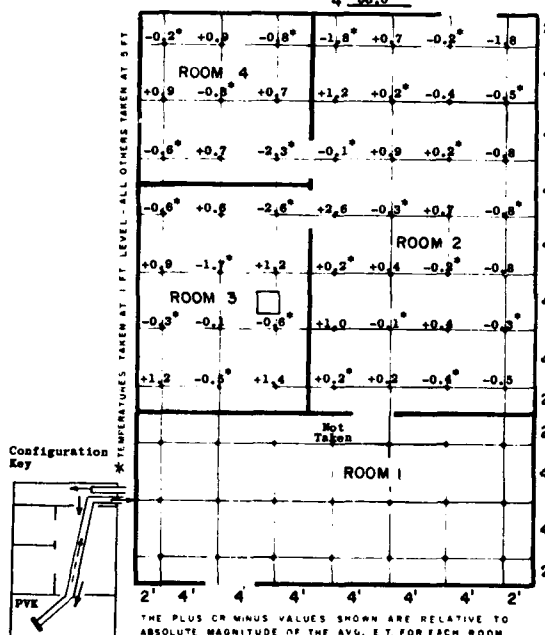
CONFIGURATION NO. 2-N  
 TEST NO. 46 (Minimum Shelter Response)  
 VENTILATION RATE 24.0 cfm/occ  
 AVG. SHELTER E.T. 80.0°  
 AVG. E.T. OF ROOM

1 80.2  
 2 78.3  
 3 83.1  
 4 82.0



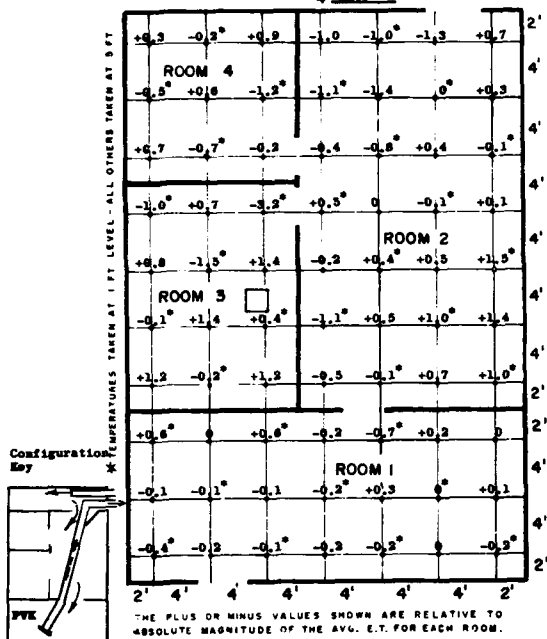
CONFIGURATION NO. 2-N  
 TEST NO. 46 (Maximum Shelter Response)  
 VENTILATION RATE 25.0 cfm/occ  
 AVG. SHELTER E.T. 80.0°  
 AVG. E.T. OF ROOM

1 85.6  
 2 85.6  
 3 89.5  
 4 88.6



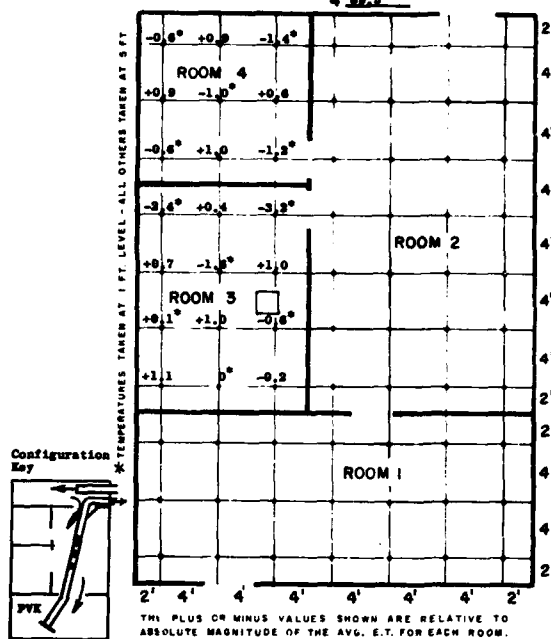
CONFIGURATION NO. 2-B  
 TEST NO. 47 (Maximum Shelter Response)  
 VENTILATION RATE 25 cfm/occ  
 AVG. SHELTER E.T. 87.0°  
 AVG. E.T. OF ROOM

1 86.2  
 2 85.4  
 3 88.0  
 4 88.7



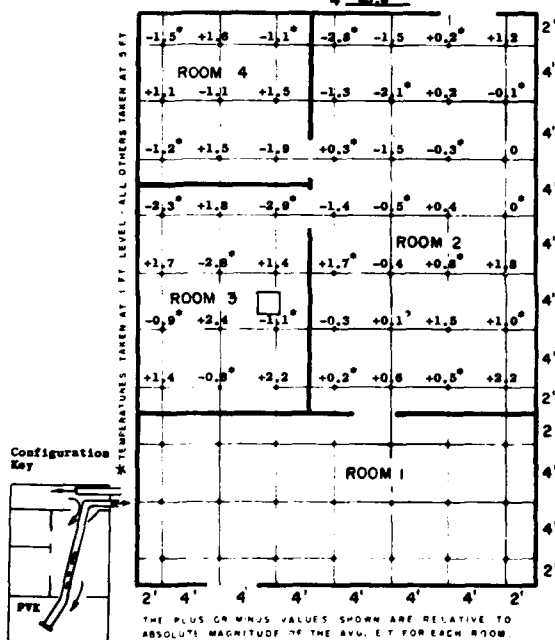
CONFIGURATION NO. 2-B  
 TEST NO. 47 (Maximum Shelter Response)  
 VENTILATION RATE 25 cfm/occ  
 AVG. SHELTER E.T. 87.0°  
 AVG. E.T. OF ROOM

1 86.2  
 2 85.4  
 3 88.0  
 4 88.7



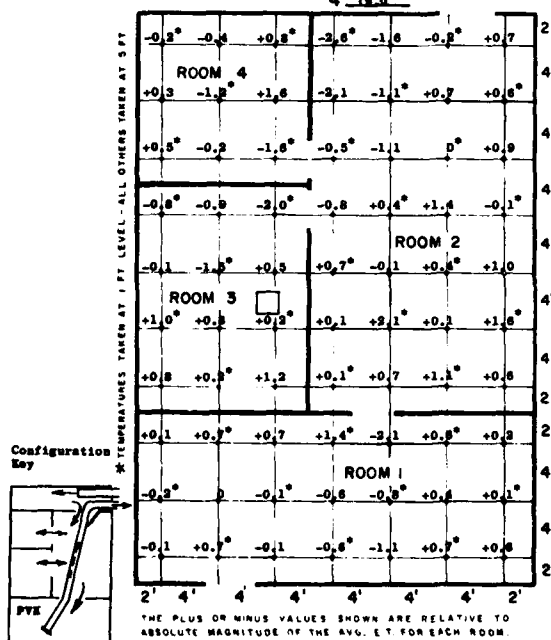
CONFIGURATION NO. 2-B  
 TEST NO. 47 (Minimum Shelter Response)  
 VENTILATION RATE 24 cfm/occ  
 AVG. SHELTER E.T. 79.3°  
 AVG. E.T. OF ROOM

1 77.8  
 2 77.8  
 3 84.6  
 4 83.8



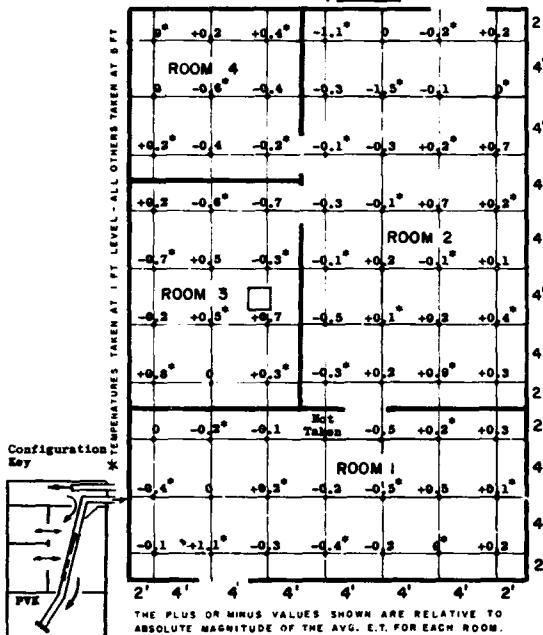
CONFIGURATION NO. 2-BP  
 TEST NO. 48 (Minimum Shelter Response)  
 VENTILATION RATE 25 cfm/occ  
 AVG. SHELTER E.T. 79.3°  
 AVG. E.T. OF ROOM

1 78.9  
 2 78.1  
 3 80.4  
 4 78.0



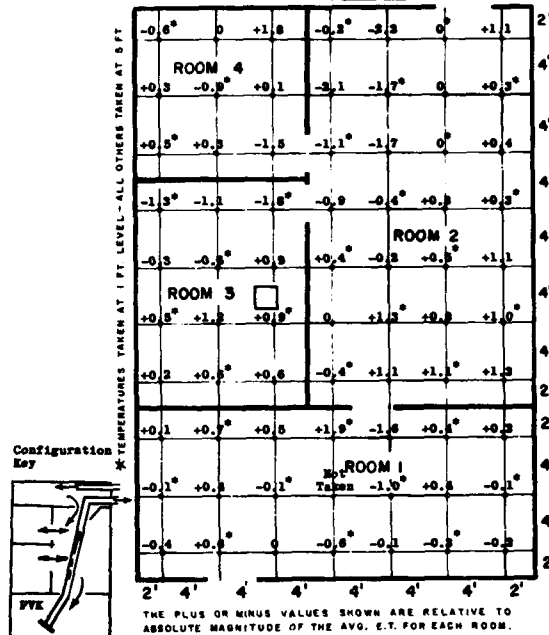
CONFIGURATION NO. 2-BP  
 TEST NO. 48 (Minimum Shelter Response)  
 VENTILATION RATE 24.5 cfm/occ  
 AVG. SHELTER E.T. 85.6°  
 AVG. E.T. OF ROOM

1 85.0  
 2 85.3  
 3 86.1  
 4 85.7



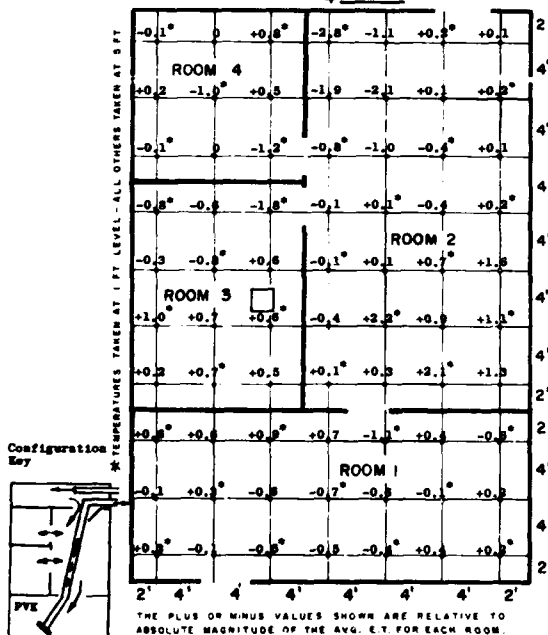
CONFIGURATION NO. 2-BP  
 TEST NO. 48 (Minimum Shelter Response)  
 VENTILATION RATE 25 cfm/occ  
 AVG. SHELTER E.T. 80.8°  
 AVG. E.T. OF ROOM

1 80.5  
 2 78.1  
 3 80.9  
 4 79.7



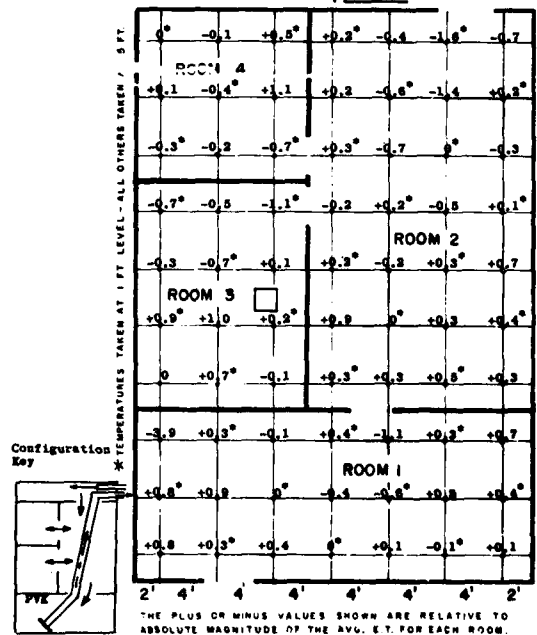
CONFIGURATION NO. 2-BP  
 TEST NO. 48 (Minimum Shelter Response)  
 VENTILATION RATE 25 cfm/occ  
 AVG. SHELTER E.T. 79.3°  
 AVG. E.T. OF ROOM

1 80.6  
 2 77.9  
 3 81.0  
 4 80.3

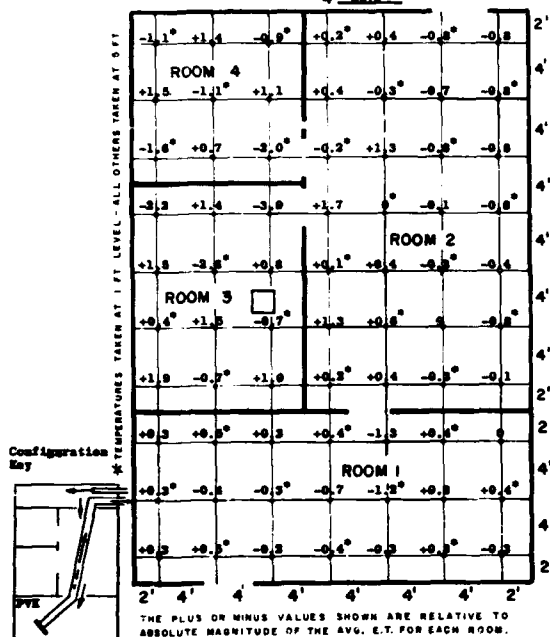


CONFIGURATION NO. 2-P  
 TEST NO. 50 (Maximum Shelter Response)  
 VENTILATION RATE 13.5 cfm/occ  
 AVG. SHELTER E.T. 86.0°  
 AVG. E.T. OF ROOM

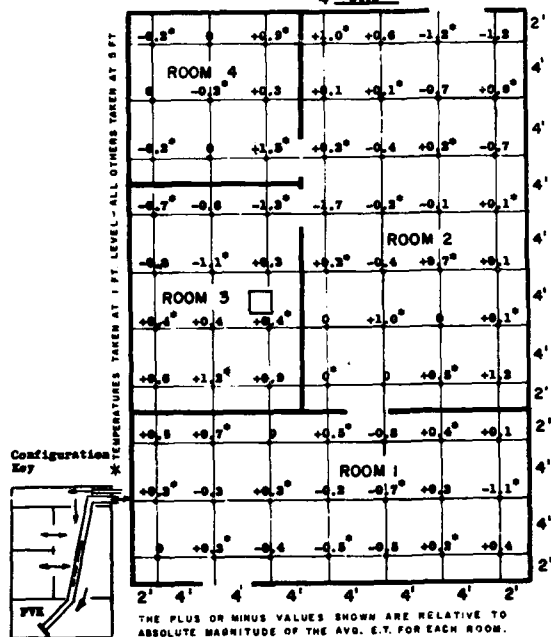
1 87.0  
 2 85.6  
 3 87.3  
 4 87.0



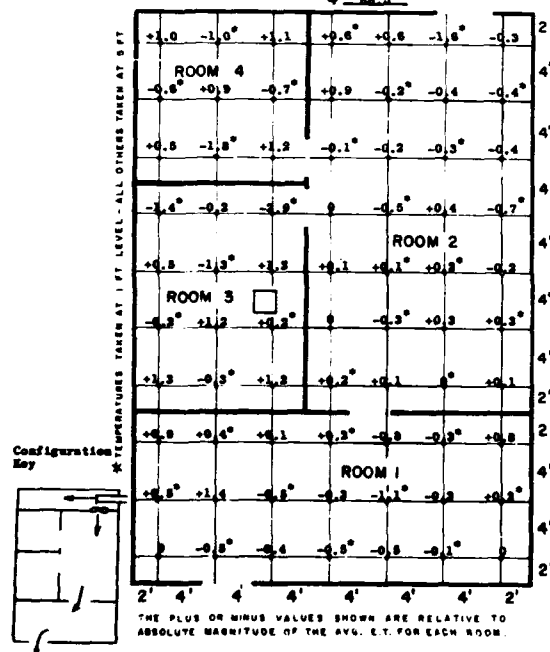
CONFIGURATION NO. 2-H  
 TEST NO. 51  
 VENTILATION RATE 23.0 cfm/occ  
 AVG. SHELTER E.T. 83.1°  
 AVG. E.T. OF ROOM  
 1 83.3  
 2 82.1  
 3 86.3  
 4 85.3



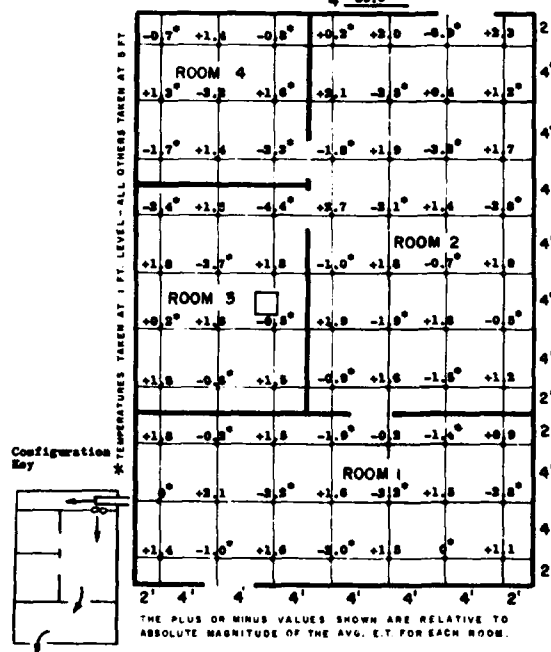
CONFIGURATION NO. 2-P  
 TEST NO. 52  
 VENTILATION RATE 23.0 cfm/occ  
 AVG. SHELTER E.T. 83.6°  
 AVG. E.T. OF ROOM  
 1 83.7  
 2 83.9  
 3 84.5  
 4 84.3



CONFIGURATION NO. 1-H  
 TEST NO. 53 (Maximum Shelter Response)  
 VENTILATION RATE 23 cfm/occ  
 AVG. SHELTER E.T. 86.6°  
 AVG. E.T. OF ROOM  
 1 86.2  
 2 85.4  
 3 88.9  
 4 88.1

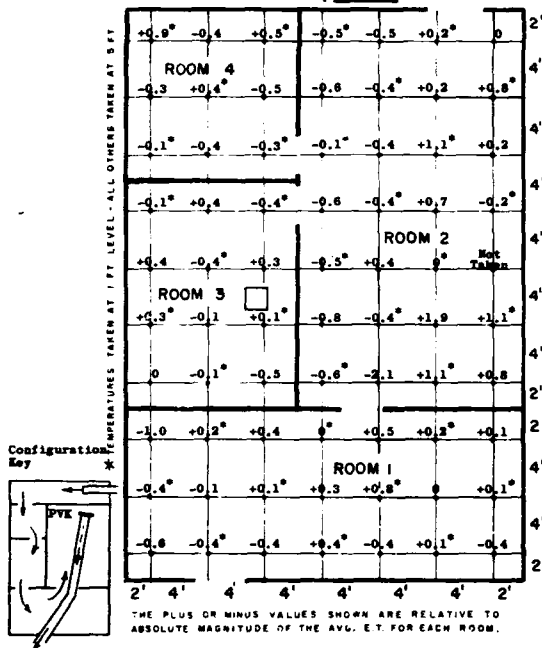


CONFIGURATION NO. 1-P  
 TEST NO. 54  
 VENTILATION RATE 2.0 cfm/occ  
 AVG. SHELTER E.T. 84.0°  
 AVG. E.T. OF ROOM  
 1 86.7  
 2 84.8  
 3 86.2  
 4 88.8



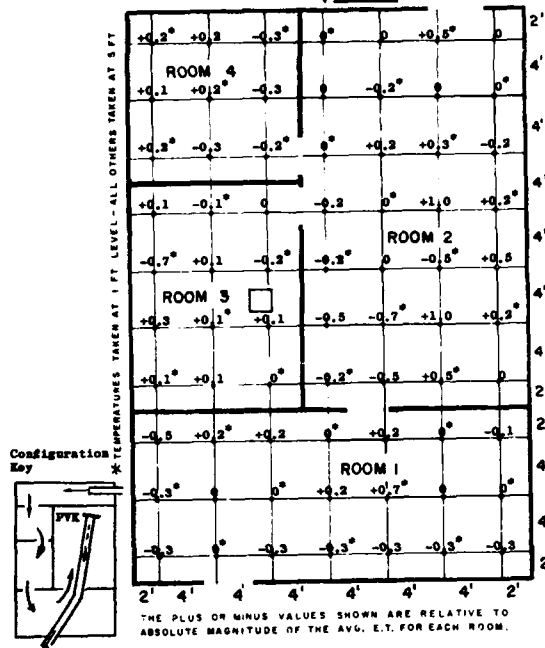
CONFIGURATION NO. 3-H  
 TEST NO. 55 (Maximum Shelter Response)  
 VENTILATION RATE 25.34 cfm/occ  
 AVG. SHELTER E.T. 78.7°  
 AVG. E.T. OF ROOM

1 80.3  
 2 80.9  
 3 77.3  
 4 75.9



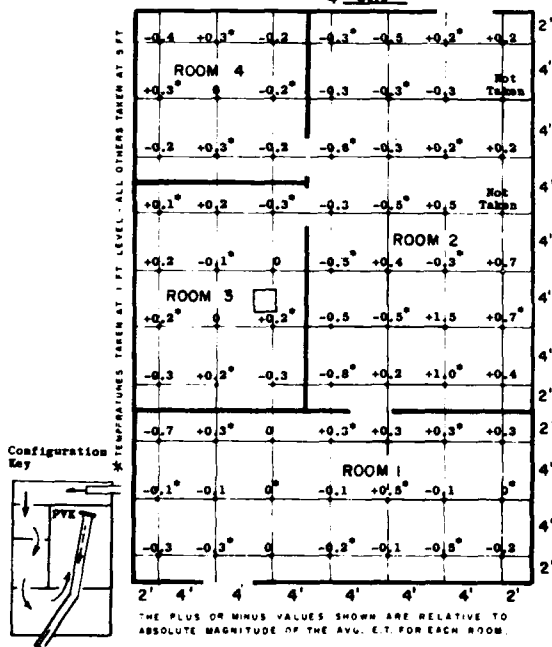
CONFIGURATION NO. 3-H  
 TEST NO. 56 (Maximum Shelter Response)  
 VENTILATION RATE 28 cfm/occ  
 AVG. SHELTER E.T. 85.5°  
 AVG. E.T. OF ROOM

1 85.3  
 2 85.1  
 3 84.8  
 4 84.3



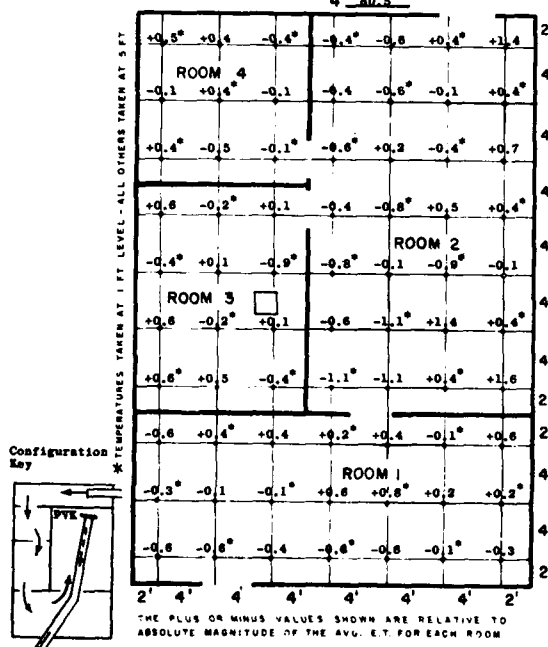
CONFIGURATION NO. 3-H  
 TEST NO. 56  
 VENTILATION RATE 18 cfm/occ  
 AVG. SHELTER E.T. 85.8°  
 AVG. E.T. OF ROOM

1 85.4  
 2 86.9  
 3 84.8  
 4 84.0



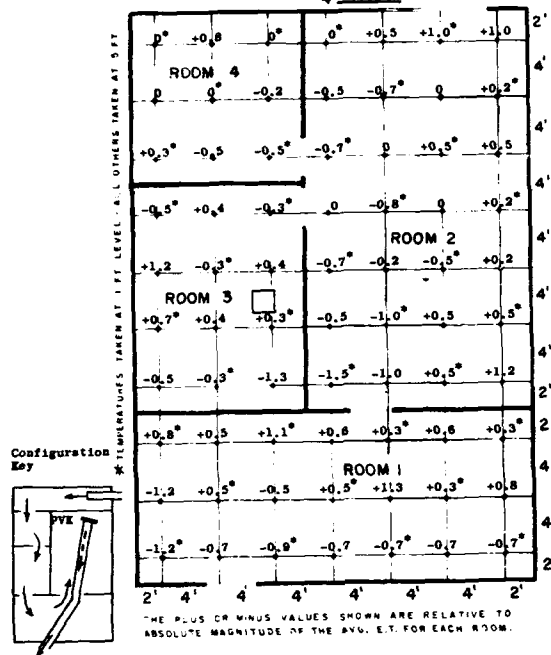
CONFIGURATION NO. 3-H  
 TEST NO. 57  
 VENTILATION RATE 18.0 cfm/occ  
 AVG. SHELTER E.T. 83.0°  
 AVG. E.T. OF ROOM

1 82.8  
 2 84.8  
 3 81.7  
 4 80.5



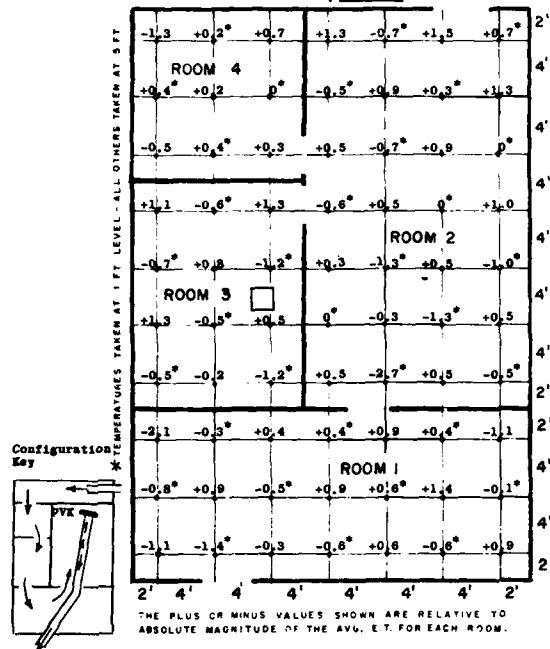
CONFIGURATION NO. 3-N  
 TEST NO. 58  
 VENTILATION RATE 18 cfm/occ  
 AVG. SHELTER E.T. 80.0°  
 AVG. E.T. OF ROOM

1 79.7  
 2 82.1  
 3 77.9  
 4 77.6



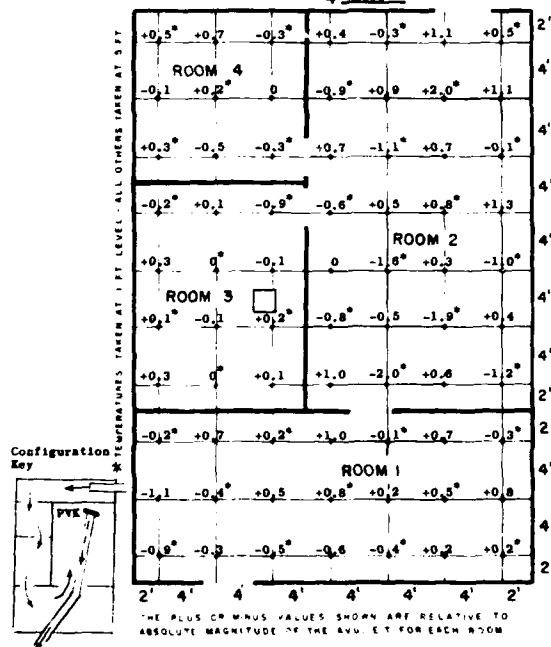
CONFIGURATION NO. 3-N  
 TEST NO. 59  
 VENTILATION RATE 10.5 cfm/occ  
 AVG. SHELTER E.T. 82.6°  
 AVG. E.T. OF ROOM

1 82.0  
 2 85.2  
 3 79.5  
 4 78.7



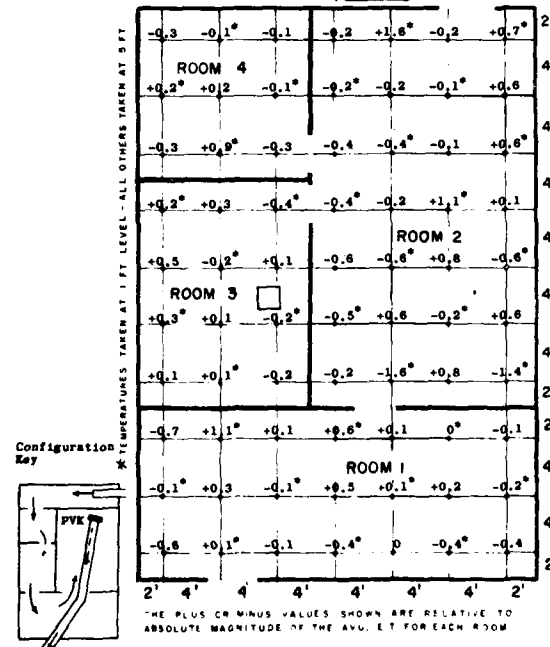
CONFIGURATION NO. 3-N  
 TEST NO. 60  
 VENTILATION RATE 10.5 cfm/occ  
 AVG. SHELTER E.T. 84.7°  
 AVG. E.T. OF ROOM

1 84.5  
 2 87.6  
 3 82.5  
 4 81.5



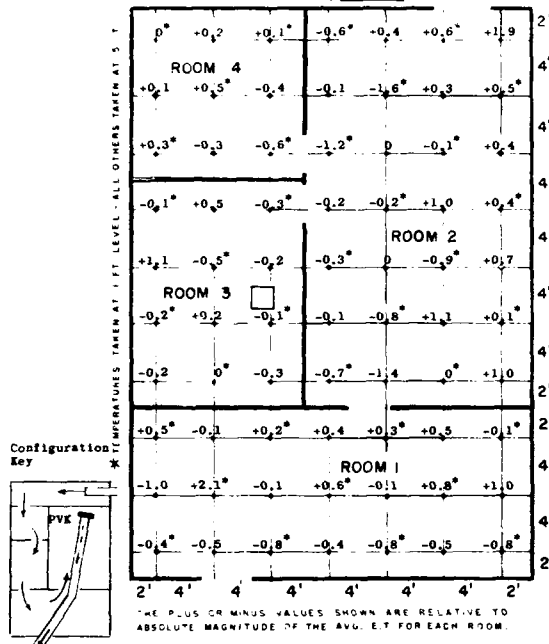
CONFIGURATION NO. 3-N  
 TEST NO. 61  
 VENTILATION RATE 13.81 cfm/occ  
 AVG. SHELTER E.T. 86.4°  
 AVG. E.T. OF ROOM

1 85.8  
 2 87.5  
 3 84.8  
 4 84.1



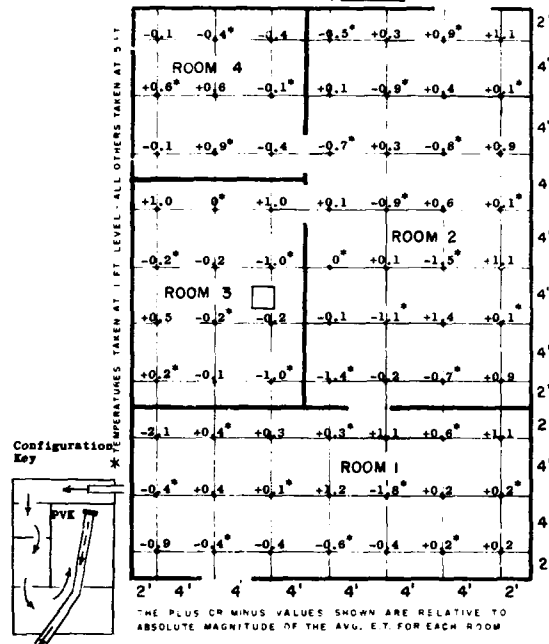
CONFIGURATION NO. 3-N  
 TEST NO. 62  
 VENTILATION RATE 13.5 cfm/occ  
 AVG. SHELTER E.T. 83.6°  
 AVG. E.T. OF ROOM

1 83.2  
 2 85.8  
 3 81.9  
 4 80.8



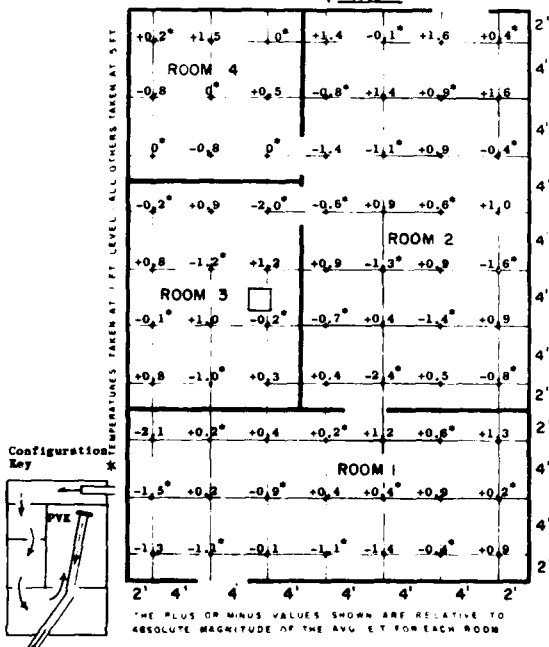
CONFIGURATION NO. 3-N  
 TEST NO. 63  
 VENTILATION RATE 13.5 cfm/occ  
 AVG. SHELTER E.T. 80.2°  
 AVG. E.T. OF ROOM

1 80.0  
 2 83.4  
 3 78.3  
 4 78.3



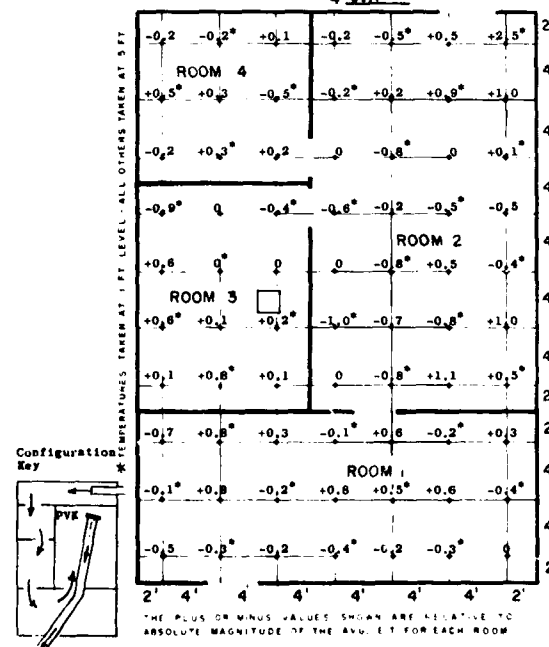
CONFIGURATION NO. 3-N  
 TEST NO. 64  
 VENTILATION RATE 8.1 cfm/occ  
 AVG. SHELTER E.T. 82.5°  
 AVG. E.T. OF ROOM

1 82.9  
 2 86.4  
 3 80.0  
 4 77.1



CONFIGURATION NO. 3-N  
 TEST NO. 65 (Maximum Shelter Response)  
 VENTILATION RATE 13.5 cfm/occ  
 AVG. SHELTER E.T. 86.5°  
 AVG. E.T. OF ROOM

1 86.4  
 2 88.3  
 3 85.5  
 4 84.7



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Protective Structures Development Center, Fort Belvoir, Va.  
PSDC-TR-17, 15 July 1965

AIR DISTRIBUTION IN A MULTI-ROOM SHELTER USING A PACKAGE VENTILATION KIT, prepared by Engineering and Industrial Experiment Station, College of Engineering, University of Florida.

This report covers ventilation studies to determine the suitability of a Package Ventilation Kit (PVK) to adequately ventilate an adiabatic, compartmented, simulated protective shelter. Individual simulated occupants were used. Conditioned ventilation air at the 1% high design day (Springfield, Va.) was delivered to the shelter at varying rates and thermal responses for shelter and individual rooms measured. A habitable thermal environment, as measured by 85° ET maximum, could not be maintained in all of the shelter rooms through a complete diurnal cycle in supply or exhaust at any ventilation rate tested (8 to 25 cfm per occupant) without auxiliary air moving devices (Punkah Pumps). At criterion 85° ET average, diurnal cycle, the entire shelter could be adequately ventilated by the PVK (exhaust) at 14 cfm per occupant with Punkah Pumps. For these same conditions with PVK as an air supply 16 cfm were required. Side rooms at diurnal cycle exceeded average 85° ET for all ventilation rates without Punkah Pumps.

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1. Ventilation  
Package Ventilation Kit  
Air Distribution  
Thermal Environment  
Effective Temperature  
Punkah Pumps  
Protective Shelters

2. Contract No. DA-18-202-ENG-3580

I. Juan O. Gonzalez

II. David W. Taylor

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Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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## S U M M A R Y

### AIR DISTRIBUTION IN A MULTI-ROOM SHELTER USING A PACKAGE VENTILATION KIT

Technical Report Prepared for  
The Protective Structures Development Center  
Joint Civil Defense Support Group  
Ft. Belvoir, Virginia

Prepared By

ENGINEERING AND INDUSTRIAL EXPERIMENT STATION  
College of Engineering  
University of Florida  
Gainesville, Florida

This report covers ventilation studies to determine the suitability of a Package Ventilation Kit (PVK) to adequately ventilate an adiabatic, compartmented, simulated protective shelter. Individual simulated occupants were used. Conditioned ventilation air at the 1% high design day (Springfield, Va.) was delivered to the shelter at varying rates and thermal responses for shelter and individual rooms measured. A habitable thermal environment, as measured by 85° ET maximum, could not be maintained in all of the shelter rooms through a complete diurnal cycle in supply or exhaust at any ventilation rate tested (8 to 25 cfm per occupant) without auxiliary air moving devices (Punkah Pumps). At criterion 85° ET average, diurnal cycle, the entire shelter could be adequately ventilated by the PVK (exhaust) at 14 cfm per occupant with Punkah Pumps. For these same conditions with PVK as an air supply 16 cfm were required. Side rooms at diurnal cycle exceeded average 85° ET for all ventilation rates without Punkah Pumps.

Contract No. DA-18-020-ENG-3580  
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1. ORIGINATING ACTIVITY (Corporate author) Engineering & Industrial Experiment Station College of Engineering, Univ. of Florida Gainesville, Florida		2a. REPORT SECURITY CLASSIFICATION	
		2b. GROUP	
3. REPORT TITLE Air Distribution in a Multi-Room Shelter Using a Package Ventilation Kit			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final report			
5. AUTHOR(S) (Last name, first name, initial) D. W. Taylor Juan O. Gonzalez, Jr.			
6. REPORT DATE 15 July 1965		7a. TOTAL NO. OF PAGES Eighty-three (83)	7b. NO. OF REFS Nine (9)
8a. CONTRACT OR GRANT NO. OCD-PS-65-17		9a. ORIGINATOR'S REPORT NUMBER(S) PSDC-TR-17	
b. PROJECT NO. 1200			
c. Task No. 1210			
d. Work Unit 1217A		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
10. AVAILABILITY/LIMITATION NOTICES			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Protective Structures Development Center Fort Belvoir, Virginia	
13. ABSTRACT <p>This report covers ventilation studies to determine the suitability of a Package Ventilation Kit (PVK) to adequately ventilate an adiabatic, compartmented, simulated protective shelter. Individual simulated occupants were used. Conditioned ventilation air at the 1% high design day (Springfield, Va.) was delivered to the shelter at varying rates and thermal responses for shelter and individual rooms measured. A habitable thermal environment, as measured by 85° ET <u>maximum</u>, could not be maintained in all of the shelter rooms through a complete diurnal cycle in supply or exhaust at any ventilation rate tested (8 to 25 cfm per occupant) without auxiliary air moving devices (Punkah Pumps). At criterion 85° ET <u>average</u>, diurnal cycle, the entire shelter could be adequately ventilated by the PVK (exhaust) at 14 cfm per occupant with Punkah Pumps. For these same conditions with PVK as an air supply 16 cfm were required. Side rooms at diurnal cycle exceeded <u>average</u> 85° ET for all ventilation rates without Punkah Pumps.</p>			

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